WINDBREAK AND SHELTERBELT TECHNOLOGY

FOR

INCREASING AGRICULTURAL PRODUCTION

S&T/FENR Agro-forestation
SERIES # 6
Rm. 515-D, SA-18
Agency for International
Development
Washington, D.C. 20523
January 12, 1987

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Compiled by Michael D. Benge, Agroforestry Officer, Bureau for Science and Technology, Office of Forestry, Environment, and Natural Resources, Agency for International Development, Washington, D.C. 20523

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SECTION I

AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C. 20523

INFORMATION MEMORANDUM

SUBJECT: Windbreak and Shelterbelt Technology for Increasing Agricultural Production

How would you like to be able to increase farmers' millet yields by 20% without introducing new and improved plant material and without the addition of costly irrigation, fertilizers and pesticides? And soybeans by 20-25%? Tomatoes and beans by 16-40%? Sugar beets by 10-50%? Wheat by 24-43%? Maize by 87%? Other cereals by 67%? Citrus by 6.5 fold?

Attached are the table of contents, select abstracts and the addresses of the attendees from the Proceedings of the International Symposium on Windbreak Technology held in Lincoln, Nebraska, June 23-27, 1986. The enclosed abstracts were selected as to their relevance to application in the developing countries. Copies of the full text of the papers can be obtained either by (1) writing the authors or (2) purchasing a copy of the conference text book (containing invited papers only), which will be available in the 1st quarter of 1987, from the University of Nebraska, attention Dr. Jim Brandle.

The 20% millet yield increase resulted from the establishment of windbreaks in the Majjia Valley in Niger, as concluded in a recent evaluation supported by A.I.D's FVA Bureau, the S&T/FENR Forestry Support Program and CARE. Over 500 km of windbreaks comprising double rows of neem trees (Azadirachta indica) have been established in an A.I.D.-funded project implemented by CARE and GON.

The other yield increases were achieved in China, the U.S. and Canada, and conditions under which these gains were achieved may not be representative of most LDC conditions. **But significant yield increases can be achieved by establishing windbreaks and shelterbelts in the LDCs, especially in windy, dry or sandy areas.**

Windbreaks and shelterbelts make more moisture available for plants by decreasing wind velocity across the soil, which reduces the evaporation of surface soil moisture. Wind erosion is also decreased, especially on sandy soils. Wind-blown sand shears newly emerged plants or buries them, causing a high mortality rate.

Windbreaks and shelterbelts exemplify the interface between agriculture and forestry. The neem trees provide not only protection from the wind but also valuable firewood for the people in the Majjia Valley. Neem was chosen because it grows relatively well in areas with low rainfall and in nutrient-poor soils. Also, neem leaves are unpalatable to most livestock, which makes it ideal for planting in areas that are under pressure by browsing animals. Another potential benefit of the windbreaks is the naturally occurring pesticide found in neem seeds and leaves. In India, the seeds and leaves are mixed with stored grains to reduce post-harvest losses to insects. Also, a water emulsion made from extracts from the seeds is very effective as a pesticide when sprayed on plants and on grain sacks. This pesticide reportedly controls over 100 species of insects, mites, and nematodes--including such economically important pests as the desert and migratory locusts, rice and maize borers, pulse beetle and rice weevil, rootknot and reneform nematodes, and citrus red mite.

Windbreaks not only can increase crop yields and provide needed wood products and pesticides, but, can provide abundant amounts of forage for livestock if other species of trees such as Prosopis and Leucaena are interplanted with trees with leaves not palatable to livestock (such as neem).

Most research on the positive effects of windbreaks and shelterbelts has been conducted in developed countries, such as the U.S. and Canada, where considerable published results are available. Some positive research has been done in developing countries, such as those in the Near East and Niger, but most of this information is not readily available.

Michael D. Benge
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January 12, 1987

SECTION II

International Symposium on Windbreak Technology

Proceedings

Edited by
David L. Hintz
James R. Brandle

Lincoln, Nebraska
June 23-27, 1986

Great Plains Agricultural Council Publication No. 117

ACKNOWLEDGEMENTS

The Planning Committee would like to express its sincere appreciation to Lenora Hanna, Carol Howell and Pamela Lionberger of the Department of Forestry, Fisheries, and Wildlife, UNL and to Carole Riese, Soil Conservation Service for the many hours devoted to the preparation of th Symposium materials, and to Mr. Gary Wells, Soil Conservation Service fo the design of the Symposium logo.

Special thanks go to the sponsors who provided the initial funding that made the Symposium possible.

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The Planning Committee also wishes to acknowledge the following firms and establishments for their contributions and support of the Symposium.

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The Planning Committee gratefully acknowledges the following agencies and corporations which have contributed financially to the success of the Symposium. They have displays located in the Riverside Room in the lower level of the Hilton and we encourage you to visit with them during the week.

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International
Windbreak
Symposium

September 22, 1986

TO: Participants - International Windbreak Symposium

FROM: Jim Brandle, Dave Hintz

Enclosed are a number of revised pages for your copy of the Proceedings of the Symposium. There are several new papers that were unavailable in June as well as a new list of all participants. Since the Symposium was the annual meeting of the Great Plains Agricultural Council-Forestry Committee, the minutes of the Committee are also enclosed.

The bibliography is almost complete and will be available soon (October). It is still $15.00 U.S. and may be ordered from the Department of Forestry, Fisheries and Wildlife. Please makes checks payable to the International Windbreak Symposium.

Finally, progress on the textbook is good, and we still anticipate going to the publisher by January. The pre-publication price is $45.00 U.S. and will be available until December 1986. Once the order is placed with Elsevier we will no longer accept orders. After January, orders will need to be placed directly with Elsevier and the cost will most likely be higher. If you didn't order your copy at the Symposium, do so before the end of the year. Payment or a Purchase Order should accompany your order. Make checks payable to the International Windbreak Symposium.

Finally, Dave and I enjoyed the Symposium a great deal. We believe it was one of the best ever. Your participation and interest were major reasons for its success. We hope someone is interested in organizing the next meeting in 1990 and look forward to see many of you then. Again, thank you for making the First International Symposium on Windbreak Technology a huge success.

mt

Enclosures

University of Nebraska-Lincoln Institute of Agriculture & Natural Resources
Department of Forestry, Fisheries & Wildlife 101 Plant Industry, Lincoln, NE 68583-0814

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WELCOME TO INTERNATIONAL SYMPOSIUM ON WINDBREAK TECHNOLOGY

By Dr. Roy G. Arnold, Vice Chancellor
Institute of Agriculture and Natural Resources
University of Nebraska-Lincoln
Lincoln, Nebraska
June 23, 1986

I wish to add my word of welcome to those you have received earlier today. Welcome to the State of Nebraska, to the City of Lincoln, to the University of Nebraska, and to the International Symposium on Windbreak Technology.

Secondly, I wish to say thanks to the planners of this symposium. An event of this scope and magnitude represents a good deal of hard work by many persons from several organizations. The program is truly impressive, and I commend all of those involved in its planning.

This symposium is a highly significant event. It is timely, in terms of the choices facing farmers and ranchers in these difficult economic times for production agriculture. The sharing of information by scientists and specialists with common interests is always a stimulating experience. All of our institutions and organizations are staffed with a small number of specialists in any given area. Thus, the opportunity to interact with professional colleagues and to share common interests and information is critically important to the advancement of windbreak technology.

The physical setting for the symposium ... Nebraska in the heart of the Great Plains ... is also most appropriate. This area has a rich history of interest and commitment to the planting of trees. In his booklet, "Of Trees and Dreams", Professor Roger Welsch, Professor of English at the University of Nebraska-Lincoln, commented on the view of the early settlers regarding trees, as follows:

> "To the settlers, trees meant shelter, and quiet ... something to hide behind. Trees were planted to enclose fields and houses. Trees cut the broad landscape, the glaring sun and the endless sky into pieces the immigrant eye could more easily digest".

The first documented planting of trees in Nebraska was by a squatter named G. B. Lore in 1853. Legal efforts to encourage the practice of planting of trees soon followed. The frequently expressed concern was that reports of the lack of trees in the area would scare away potential settlers.

In 1861, the Nebraska Territorial Legislature adopted legislation which provided tax relief to any landowner who planted trees on their farms, in the amount of $50 tax relief per acre of land planted to trees. This was rescinded in 1864, due to the impact on tax revenues. Reportedly, some farmers met their total tax obligation through planting of trees.

In 1869, the Nebraska State Legislature enacted a similar exemption, in this case amounting to $100 of tax relief per acre of trees planted. In the 1870's, legislation was adopted which established bounties for tree planting. Counties were required to pay $3.33 to landowners for each three acres of forest acres planted in rows.

Prominent and powerful figures such as J. Sterling Morton, territorial governor in the 1850's, and Robert W. Furnas, Nebraskas state governor in the 1870's, urged the adoption of tree culture as a means of moisture conservation. Arbor Day was established in Nebraska in 1872 as an annual holiday. This holiday has since been adopted as a national holiday, and is unique in its positive impact and reminder of our relationships and obligations to the natural world which surrounds us.

The Timber Culture Act, which was adopted in 1873, provided additional land for settlers who planted trees. Initially, an additional one quarter section of land was provided for forty acres of planted trees, later reduced to ten acres.

Tree protection laws were also established. An 1873 Nebraska law stated, "Any person who willfully or maliciously ... injures or destroys any trees equaling or exceeding $35 in value ... shall be imprisoned at hard labor for a period not greater than ten years and not less than one year, and shall pay double the value of the trees to the property owner". As Roger Welsch pointed out, any person who had a conflict or disagreement with their neighbor would be safer to whip out their gun and shoot him than to cut down his trees. He could always plead self defense, but no such subterfuge could be claimed by a tree mutilator ... the penitentiary for him!

It is also noteworthy that Nebraska has the only totally man-established national forest in the U.S.!

The frequent cycles of drought in the Great Plains, specifically in the 1860's, the 1870's, and particularly the 1930's, brought the planting of shelterbelts to the forefront as a major societal goal. The statistics of the Prairie States Forestry Project, 1935-42, are truly impressive. This project involved the states of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma and Texas. These data include:

	Region	Nebraska
Number of trees planted	217 million	45 million
Number of acres planted	238,000	51,000
Number of miles of shelterbelt	18,600	4,168

* Peak year of 1939, over 10 million.
(See attached Tables for details).

A 1985 report of the Nebraska Forest Service indicates that windbreaks in Nebraska —

-- provided $19 million estimated annual increase in grain production through crop protection benefits
-- provided an additional $1.5 million annual savings in the calf crop through livestock production benefits
-- provide protection and habitat for many species of wildlife
-- provide many useful products, such as firewood, fenceposts, etc.

What is happening today? There is a continued decline in tree acreage in Nebraska, and in the Great Plains generally. Nebraska was 3% forested at the time of the pioneers. Today, 2% or less of Nebraska is covered by trees. Some predict that the forested area of Nebraska will be less than 1% by the year 2000. Since 1955, 8,500 acres of trees have been cleared annually in Nebraska.

This brings us to this symposium, and its importance. It is interesting to note that the greatest period of tree planting in the Great Plains occurred at a time of great adversity for agriculture, both economic adversity and major drought. In spite of those circumstances, people were able to focus on longer term considerations, and marshaled their resources and energies to embark on major tree planting efforts to establish windbreaks and shelterbreaks. It is interesting to note that the 1985 Farm Bill in the U.S. provided renewed emphasis on the establishment of "conservation acres". This emphasis recognizes both economic and conservation concerns, and represents a renewed opportunity to emphasize the planting of trees for long term benefits to society.

The value and benefits of tree planting and shelterbelts need to be told and sold, not in terms of what happened in the 1930's but in today's terms. People act and behave based on perceptions. I would suggest that there is a broad perception that shelterbelts are old technologies. How often have you heard the comments, we have irrigation now, we needn't worry about a repeat of the drought conditions of the 1930's. Changes and improvements in windbreak technology are not well known or well understood. We need both sound scientific data regarding newer windbreak technology, as well as a concerted effort to communicate the benefits and advantages of windbreaks for today's farmers and ranchers.

This brings us further to tonight's featured keynote speaker, Dr. J. W. "Hamish" Sturrock. Dr. Sturrock is the leader of an agrometeorology group of the Crop Research Division in New Zealand. He is located in Lincoln, New Zealand, so we are pleased to welcome him from Lincoln to Lincoln. Dr. Sturrock is a native of Scotland, specifically Edinburgh, Scotland, and holds his degrees from the University of Edinburgh and Cambridge University. His education and initial research efforts were in the field of biochemistry, specifically in the development of leaf protein for human nutrition. During his twenty years in New Zealand, he frequently raised questions regarding the lack of data and information on the influence of wind, which like the Great Plains is a common feature of his area of New Zealand, on agricultural production. This led to his being given the opportunity to organize and lead an agrometeorology research group, which focuses on the influence of wind and the benefits of windbreaks and agroforestry on agricultural production in New Zealand. Dr. Sturrock's topic is "Shelter: Its management and promotion". Please join me in welcoming Dr. Hamish Sturrock.

SHELTER: ITS MANAGEMENT AND PROMOTION

Dr. J. W. Sturrock
Crop Research Division
Department of Scientific and Industrial Research
Lincoln, New Zealand

In the future the role of shelter will increase in importance. Limited crop water supplies and higher costs of irrigation will necessitate the use of windbreaks for conserving crop water. In addition, the ability to combine shelter with the production of commercial timber will gain in importance. Compatability between shelter and wood production is important not only for directly raising the economic returns from shelter but also in some countries for countering the unrealistic divorce between agriculture and forestry. These, and other benefits from shelter will be achieved more fully only with improved tree management. Some factors responsible for the generally poor standard of farm shelterbelts are examined. Management objectives will vary with the type of shelter, and the environmental and economic factors operating in individual countries and regions. An example of enlightened management from New Zealand will be illustrated and discussed, where the objectives include maintenance of aerodynamic efficiency, production of an eventual timber crop and minimization of shelter disadvantages. Successful promotion and recognition of shelter as a technology in its own right are largely dependent on wider dissemination of practical techniques to ensure improved shelter standards. To this end some of the measures needed to improve extension advice and co-ordination and promotion generally are considered. Finally, important research topics from which information could further promote use of shelter are outlined.

THE INFLUENCE OF FIELD WINDBREAKS ON VEGETABLE AND SPECIALTY CROPS

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Ridgetown, Ontario, CANADA

ABSTRACT

Many vegetable and specialty crop producing areas in North America are vulnerable to wind damage. They are becoming increasingly so. This seems especially true for many early-season vegetable plantings on coarse-textured soils. Many of the crops grown thereupon are high value and thus dictate the use of expensive cultural practices. This necessitates that field windbreaks are of major import if we are to adequately protect these crops and soils from wind damage.

Some of the first research studies reported of wind protection on vegetable and specialty crops can be found from Denmark as early as 1909.

The improvement in crop quality is a major benefit of wind protection. Research has shown this to be true, exemplified by: an increase in sugar content of beets; lower nicotine content in tobacco; less physical abrasions in virtually all crops but perhaps cole crops in particular; and earlier ripening and maturity in such crops as tomatoes, potatoes, strawberries, and peppers.

Almost without exception the protection of these crops from damaging winds has resulted in beneficial yield responses. In most cases the crop yield increases in the lee of a shelter, either living or artificial, have been very significant. Some increases reported are only a little short of phenomenal.

Crop yield increases have been noted in the lee of windbreak out to about the 10H area (i.e. when H is equal to the height of the windbreak). Most often the maximum yield response has occurred in the 3H to 6H range. Generally, it can be said that for most of the crops studied the yield increase due to wind protection would approximate 20 percent. The range of yield increases vary from 5 percent to as much as 50 percent. There are very few documented cases where no yield increases have been found.

ANNUAL HERBACEOUS WINDBARRIERS (WINDBREAKS) FOR THE PROTECTION OF CROPS, SOILS AND FOR WATER CONSERVATION

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and

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ABSTRACT

Annual herbaceous windbarriers have certain advantages over perennial woody (tree) shelterbelts in that they are easier, faster, and cheaper to establish, and allow more flexibility in the farming operation. Their primary function is to reduce windspeed, which in turn generally improves growing conditions for the adjacent plants by improving temperature and moisture conditions. Annual windbarriers are effective in preventing wind erosion, preventing sandblast damage to crop plants, and in trapping snow where it will be of maximum benefit in increasing soil water. Barrier porosity should be 65 to 75 percent for snow management and 40 to 50 percent for all other applications. Plants used should be as lodging resistant as possible. Barriers should be comprised of two or more rows of plants, oriented perpendicular to the erosive (or snow-laden) winds or on the contour, spaced properly so the desired end result will be achieved, and established early enough to give the necessary protection to the adjacent area.

THE USE OF PERENNIAL HERBACEOUS BARRIERS (WINDBREAKS) FOR WATER CONSERVATION AND THE PROTECTION OF SOILS AND CROPS

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Mandan, North Dakota

and

J. K. Aase
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Northern Plains Soil and Water
Research Center
Sidney, Montana

ABSTRACT

Wind erosion and rainfall deficiencies are reoccurring detriments to a sustainable agricultural production system for the semiarid U. S. Great Plains. A system of tall wheatgrass (Agropyron elongatum) barriers planted in single- or double-rows at interval spacings of 15 m effectively reduced windspeed at a 0.3 m height above the soil surface 45%, reduced potential wind erosion by 93.4% on a year-round basis, and increased storage of significant amounts, 63 mm or more, of soil water through snow management (trapping) compared to unprotected open field areas. The grass barrier system had positive effects on microclimate parameters; increased soil temperature in early spring, decreased soil temperature in June due to greater canopy cover, reduced surface soil (upper 100 mm) drying rate and decreased abrasive wind action to the crop. The grass barrier system provides a bonus from snow management for increasing soil water supplies, thereby substantially reducing the risk of crop failure in various cropping systems when properly fertilized. The tall wheatgrass barrier system of conservation farming provides a viable alternative herbaceous-wind barrier system to protect our soil and water resources.

MANAGING CROP WATER USE WITH WINDBREAKS

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ABSTRACT

Introduction:

Benefits from windbreaks have been documented in terms of increased wildlife habitat, energy conservation, fuel supply, reduced wind erosion of soil, water conservation, and increased crop yields.

The farmer is primarily interested in benefits from increased crop yields because that is how he justifies the expense of establishing the windbreak system. Only recently have some of the costs and benefits of windbreaks been quantified.

Yield increases have been reported for many years and vary considerably from area to area and from year to year depending on the windbreak design, crop, and climate. Windbreaks can be designed to increase water use efficiency by the crop as well as increased water conservation from snowfall by increasing the amount of moisture trapped and stored in the soil.

In order to compare windbreak benefits and benefits from other conservation practices, on a uniform basis, a method is needed to estimate benefits in comparable units.

Increased moisture storage within the soil profile can be easily measured using a neutron gauge or other methods. These are point measurements and would require many measurements throughout the field in order to determine the average amount of moisture conserved for the field.

If no increased moisture results from the windbreak or other practice but the crop is able to utilize the stored moisture more efficiently where protection is provided then measurement of soil moisture may not provide the needed information for evaluation. Increased crop yields from the protected area compared to the unprotected area may be a better indicator of the water conservation benefit.

A method is needed that can convert the change in crop yield to equivalent water conservation. In this way benefits from increased yields can be estimated based on all or a portion of the field and compared to measured soil moisture changes on fields that may occur before the growing season or during periods of fallow.

This paper discusses a method that can be used to convert changes in crop yield to equivalent soil moisture. The method may be used for evaluating benefits from many conservation practices including windbreaks. It is crop and site specific yet the method can be applied anywhere with a minimum of data.

Crop Yield Response to Water:

Under dryland or rainfed agriculture the limiting factor in production is most often available water. Rainfall does not usually occur at the needed frequency or amount for optimum yields. Conservation practices may be applied to increase the amount of rainfall entering the soil by restricting runoff or increasing the soil infiltration rate or both. Conservation practices such as windbreaks or crop residue use may also increase the water use efficiency of the stored soil moisture by reducing the loss from the soil by evaporation or by reducing the rate of transpiration of the crop or both.

Yield Increases Reported:

Several investigators have studied the effect of various conservation practices on increased crop yields. The paper lists the ranges in increased yields reported for various crops by researchers for several locations for windbreaks. The table could be expanded to include other conservation measures.

The yield increase from windbreaks depends upon the design of the windbreak. Density, height, spacing, and orientation will affect the windbreak efficiency as well as the area over which the yield is calculated. Windbreaks are generally effective over only 10-15 heights.

Assessing Effects of Windbreaks on Moisture Conservation:

The effect of windbreaks on the amount of moisture conserved should be based on average increased yields for the area of concern. Various sections of the field may be considered in assessing the effectiveness of windbreak design. The equivalent moisture conserved for one crop can then be evaluated in terms of its effect on yield of other crops. This analysis may be useful to the grower in determining whether or not to change crops or crop rotations, or in deciding whether or not to implement additional conservation practices. Decisions can be made on anticipated yields with and without conservation practices by crop.

Conclusion:

The effect of windbreaks and other water conservation practices can be evaluated in terms of change in yield for the crop grown compared to a check plot. The change in yield can be converted to equivalent moisture if the relationship between crop ET and yield is known. Equivalent moisture conserved by a practice can be assessed in terms of its effect on

LAYOUT AND DESIGN CRITERIA FOR THE PROTECTION OF CROPS

Sherman J. Finch
USDA-Soil Conservation Service
Davis, California

ABSTRACT

Windbreaks are used to reduce wind erosion and reduce damage to crops either by blowing soil or by wind damage. Criteria for the layout and design of windbreaks are discussed. There is discussion on the siting of belts on hilly terrain. The design of barriers, the heights of windbreaks, and the heights of crops are explained. Maximum wind protection of crops is found between 2 to 6H. Windbreaks should be designed to keep wind velocities at or below 3 m sec^{-1}.

PLANT RESPONSE TO WIND

Dr. J. Grace
University of Edinburgh
Edinburgh, Scotland

The agricultural benefit of shelter is evident from the extensive literature which has accumulated since the turn of the century. A review of the pattern of response shows that the benefit is erratic, varying between years, locations and species. At a physiological and biophysical level, the response is likely to depend on several, related, processes. Firstly, the surface temperature and rate of water use depend, in a complex way, on the microclimate. In bright sunshine, surface temperatures behind windbreaks are often sufficiently elevated by the reduction in windspeed to cause significant increases in growth, particularly in cold countries. A second factor, not appreciated until recently, is that plant surfaces are subject to wear and tear. In unsheltered areas, rupture of epedermal cells, cracking of the cuticle and loss of epicuticular waxes may increase surface conductance to water vapor and impair the capacity of the leaves to regulate their water loss. This may be even more important than the more familiar types of wind damage such as defoliation. A third factor, the overall water use by the sheltered crop, depends on environmental and crop parameters. It is certainly not always the case that a decrease in wind speed causes a reduction in water use, as an increase in the diffusion gradient for transpiration caused by higher surface temperatures may more than offset the reduction in turbulent transport. A final mechanism, which may especially affect the height and form of the plant rather than its growth in weight, occurs as a result of mechanical excitation *per se*. Overall, all these factors may interact in a complex fashion so that it is extremely difficult to predict the outcome of sheltering a specific crop.

EFFECTS OF WINDBREAK STRUCTURE ON WIND FLOW

Gordon M. Heisler
Northeastern Forest Experiment Station

David R. DeWalle
The Pennsylvania State University

This paper is to summarize the extensive literature on how the structure of windbreaks affects the air flow around them. While the literature describes primarily empirical results from field measurements (e.g., Nageli 1946; Caborn 1957; Sturrock 1969, 1972), there is increasing work in boundary layer wind tunnels (e.g., Raine and Stevenson 1977) and in numerical modeling (e.g., Hagen et al. 1981, Wilson 1985). Most of the available design guides still originate from empirical studies, and it is still worthwhile to study some of the older works (e.g., Nageli 1946, Caborn 1957, van Eimern et al. 1964).

The horizontal extent of windbreak effects upwind and downwind is usually assumed to be proportional to windbreak height, h. Measurable reductions in windspeed have been recorded as far as 50 h to the lee of windbreaks, and rarely, even farther. Reductions of 20% or more may extend to about 25 h from the windbreak.

For windbreaks that are long relative to their windbreak height, the most important structural feature is porosity ϕ. In addition to porosity, drag and resistance coefficients can also be measured easily for artificial barriers, and these parameters are commonly used to define barrier similitude in wind tunnel testing. There is considerable scatter in measurements of structural features versus windbreak effects on wind.

Theoretically, maximum wind reductions are related closely to porosity ϕ, with low ϕ producing high maximum reductions. The relationship between maximum reductions and the horizontal extent of windbreak influence is nonlinear, because for barriers with very low ϕ, the barrier creates high turbulence that results in recovery of winds to upwind speeds closer to the barriers. Barriers of medium ϕ provide significant wind reductions over the longest distance, but "medium" seems to cover a wide range of ϕ.

Turbulence in the approach flow reduces windbreak effectiveness, particularly at far downwind positions. The turbulence may be caused by thermal instability, a rough ground surface, or other upwind barriers to flow. Differences in approach-flow turbulence, differences in height of measurement relative to windbreak height, and differences in vertical porosity gradients are responsible for much of the scatter in experimental data.

Raine and Stevenson (1977) and Hagen et al. (1981), among others, discuss effects of windbreaks on turbulence. There is a triangular "quiet" zone below a line beginning near the top of windbreaks and extending to near ground level at a distance of about 8 h to the leeward. In this zone, the turbulent velocity flucuations are reduced below values in the approach flow. Above and downwind of the quiet zone is a "wake" zone with turbulent fluctuations greater than those in approach flow. The magnitude of turbulent velocity fluctuations in the lee of windbreaks is inversely proportional to ϕ. However, there is a larger difference in turbulence generated between solid barriers and slightly porous barriers than between slightly porous and very porous barriers. Windbreaks generally reduce turbulent eddy length, regardless of their structure. Peak frequency of velocity fluctuations close to windbreaks tends to increase with porosity.

Following are some general guides for designing windbreaks:

- Artificial or natural barriers can provide similar protection, with the exception that as the approach wind direction departs from normal to the windbreak, the effective ϕ of thin artificial barriers tends to increase, whereas that of natural barriers with significant width, tends to decrease. Partly because of this effect on ϕ, there is little change in wind reductions for approach angles within 45° of the perpendicular for medium- to low-porosity tree windbreaks that are long relative to their height.
- Cross-sectional shape of natural barriers seems to have little practical significance except as it affects their porosity.
- Porosities of 20% to 50% are optimal for producing a 20% reduction in mean winds near the ground over the longest distance. Tree windbreaks of one to a few rows rarely exceed this optimal effective density.
- Single-row windbreaks can be as effective as, or more effective than, multiple-row windbreaks.
- While it is generally found that protection for the largest area is provided by barriers that have higher porosity in their lower levels than in their upper levels, a completely open lower structure creates increases in wind speed in the near lee.
- Visual porosity is a useful guide to windbreak effectiveness for natural barriers that are not very wide or have few rows.
- In selecting tree species for windbreaks, a choice must often be made between species that are dense and those with rapid height growth. Height growth is usually more important than density in obtaining wind reductions over large distances.
- In systems of similar, parallel, belts for reducing winds over large areas, the efficiency of successive belts will be less than that of the first belt.

The major problems in application of these guides are in integrating the effects of windbreaks over different meteorological conditions (wind speed and direction, thermal stability), in evaluating the effects of other nearby obstacles, and in knowing the effects of given wind conditions on the objects being protected. For natural barriers, there is the added problem of integrating effects over the life of the windbreak as height and porosity changes.

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BENEFITS OF WINDBREAKS TO FIELD AND FORAGE CROPS

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ABSTRACT

Field shelterbelts have been reported to increase yields of field and forage crops in adjacent fields in numerous studies throughout the world. The increases are due to reduced wind erosion, improved microclimate, snow retention and reduced crop damage by high winds but are at least partially offset by losses due to the land occupied by the shelterbelts and the competition of shelterbelt roots with the crop.

The amount of land occupied by the shelterbelts should be less than five percent of the total field area. Yield reduction due to shelterbelt land requirements may be minimized by careful species selection and by shelterbelt design and maintenance. Species which sprawl or spread should be avoided while upright, narrow trees give the most protection relative to the area of land occupied. The number of tree rows in a shelterbelt directly affect the land requirement so that shelterbelt recommendations generally limit the number of rows to three or less. Removal of overhanging branches limits the sprawling of shelterbelts where trees with such a growth habit have been planted.

Competition by tree roots with adjacent annual crops can seriously reduce crop yields to a distance of 2.5H (H is the shelterbelt height) or more but is strongly dependent on species selection in the shelterbelts. Green ash, caragana, Russian olive, Ponderosa pine and Siberian larch have been found to be relatively non-competitive while tamarisk, Siberian elm, black walnut and black locust were found to be more competitive. Competitive yield decreases appear to be greater in semi-arid regions than in areas with higher rainfall. Competition by competitive species may be minimized by regularly cutting roots at a distance of .75-1H from the shelterbelt to a depth of 60 cm.

Shelterbelt-induced yield increases depend on the porosity of the shelterbelts since porosity determines both the degree of wind reduction and the distance to which the shelterbelts protect crops and soil. Permeable shelterbelts in northern latitudes are sometimes desired since they allow snow to be trapped in wide, shallow drifts rather than narrow, deep drifts which are characteristic of dense shelterbelts. Insofar as crop yield increases are dependent on moisture from trapped snow, permeable shelterbelts may increase crop yields more than dense shelterbelts due to the increased snowdrift width. However, soil erosion is minimized by denser shelterbelts of 40-50% porosity so that crop losses due to soil loss or sand-blasting would be minimized by such shelterbelts. Microclimate-induced crop yield increases are also greater leeward of denser shelterbelts. Since the prevention of soil erosion is the usual motivation for shelterbelt planting, shelterbelts of 40-50% porosity are generally the most preferable.

Shelterbelt height and longevity, field width and shelterbelt orientation are major considerations in determining the effect of shelterbelts on crop yields. Generally, tall, long-lived trees, combined with fields which are as narrow as practical to a minimum of 15H and are oriented perpendicular to predominant growing-season winds, can be expected to give the greatest crop yield increases.

Crops differ in their responsiveness to shelter. Of the field and forage crops tested, winter wheat, barley, rye, millet, alfalfa and hay (mixed grasses and legumes) appear to be highly responsive to protection while spring wheat, oats and corn respond to a lesser degree.

Precipitation has an effect on percentage yield increases reported. Generally, percentage yield increases due to shelterbelts have been higher in drier regions or in drier years. However, the absolute amount of the increase does not vary in the same way and may be generally greater when moisture is not limiting. Yield increases are greater due to shelterbelts in regions with snowy winters indicating that snow trapment in these areas is a factor in increasing nearby crop yields.

Economic evaluations of field shelterbelts have varied greatly in their analysis and reporting procedures and depend for their validity on accurate figures being used to quantify the shelterbelt effects on crop yields. Some authors have concluded that shelterbelts can be expected to yield a net payback, compensating for all previous and current input costs, in fifteen years. Others have concluded that shelterbelts result in net yield decreases so that no economic benefit can be expected.

Studies in North and South Dakota in the United States and in Saskatchewan and Manitoba in Canada when combined were calculated to give an average yield increase from mature shelterbelts of 3.5% assuming that the shelterbelts occupied a strip of land 1H in width (i.e. to .5H in each field), that the yield was reduced to 50% of normal from .5 to 1H due to competition, and that the field width was 30H.

Yield increases of field and forage crops in fields protected by shelterbelts are thus well established and occur throughout the world. By proper shelterbelt design and maintenance and the use of responsive crops, shelterbelt benefits to crop yields can be optimized, to make the use of shelterbelts economically viable in addition to their main function as an effective component of a soil conservation strategy.

BASIC WIND EROSION PROCESSES

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ABSTRACT

Basic wind erosion processes are discussed under major headings of soil particle dynamics, particle flow rates, and principles and general strategies of control. Particle dynamics are described in terms of suspension, saltation, surface creep, abrasion, sorting, and threshold conditions. Soil particle flow rates are divided between all-erodible-particle case and the more common but more complex case of mixtures of erodible particles and nonerodible elements. Specific principles of wind erosion control are identified and a wind erosion equation, which estimates potential erosion from a particular field or conditions necessary to reduce potential erosion to tolerable amounts, is discussed.

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EFFECTS OF WINDBREAKS ON MICROCLIMATE

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ABSTRACT

Microclimate is the sum of many elements, most of which interact, and all of which can be modified by shelter. The cardinal effect of shelter is alteration of the pattern of mean wind velocity and turbulence. Shelter can also change the radiation and energy balance of crops, both in the lee and for a short distance to windward. Air and soil temperatures, humidity and carbon dioxide concentrations, and the concentrations of pollutants can all be altered by shelter.

The nearest attempt at a comprehensive review of the effects on shelter microclimate is that by van Eimern et al (1964) which, though now two decades old, remains essential reading. A more recent review is given by Rosenberg (1979). These reviews concentrate on the results of field experiments, and the interpretation of those results. Both include discussions of the biological effects of shelter. The present work is narrower in scope, and biological responses are, as far as possible, excluded.

Recent work on the aerodynamics of shelter has shown that there exists a quiet zone of reduced turbulence and smaller eddy size immediately behind windbreaks of all porosities. Beyond that, further downwind, lies an extended wake region of increased turbulence with eddy sizes returning to upwind scale. There is evidence to show that turbulent transport of heat, vapour and carbon dioxide is reduced in the quiet zone and enhanced in the wake. The purpose of this chapter is to assemble the evidence for the existence of these distinct zones, and to discuss the consequences of this for shelter microclimate. Use of the shelter literature is selective rather than comprehensive.

Much of the work discussed is from experiments on models, conducted either in wind tunnels or over flat fields using short fences. There are good reasons for this. Understanding of similarity requirements for model experiments is now good enough for model results to have direct relevance to full-scale shelter. Because it is easier to make measurements on scale models, and experimental conditions are easier to control, we now have more and better information on the aerodynamics of shelter from these studies than from full-scale experiments.

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Convenience is not the only reason for using models in research. Farmers use shelter to improve crop growth and yield. Sheltered plants, it is hoped, will grow larger, have more leaf area and produce higher yields than unsheltered plants. But these responses confound attempts to understand shelter microclimate.. Increased leaf areas may lead to higher evaporation rates, even though shelter may reduce water loss from a uniform crop. Increased evaporation rates may lower temperature, even though the primary effect of shelter may be to raise it. Model experiments are valuable because they allow study of the mechanisms responsible for crating shelter microclimate without the added complication of the effects of vegetation responses.

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PLANTINGS IN TROPICAL AND SEMI - TROPICAL AREAS

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ABSTRACT

This chapter reviews literature on windbreak plantings in the tropics and subtropics. The tropics are broadly defined as the area lying between the Tropics of Cancer and Capricorn with sufficient rain for agriculture to be possible without irrigation, including equatorial rainforest and monsoon regions. Two subtropical climates are identified, the mediterranean and warm-temperate. Emphasis is placed on the moist tropics. Traditional shifting cultivation has been altered by population and economic pressures, resulting in shorter fallow periods and lower yields. Crops grown in the tropics are determined by the rainfall pattern. Perennial crops are suited to areas with high precipitation throughout the year. Annual crops are grown in regions with a dry season to allow harvesting. Commercial livestock raising is important only in areas with long dry spells, but domestic livestock are vital to many landowners in the moist tropics. Because the winds affecting tropical crops are hurricanes and violent thunderstorms rather than persistent winds, they cannot be controlled by windbreaks. Crop yields show a marked response to shelter provided sufficient moisture is available, but this response varies with the type of crop. Instead of traditional windbreaks, closely spaced trimmed hedges (alley cropping) appear a favourable alternative for fallow agriculture. In subtropical regions, windbreaks are a standard management tool in the growing of many crops, particularly citrus. Shelter from the sun has been an integral part of producing such crops as cocoa, coffee and tea. Research has now shown that shade trees are often detrimental to yields once crops are past the establishment phase and can provide mutual shade. The role of shade trees has also been reduced by breeding plant varieties which do not require shade and use the full sun more efficiently. Wind erosion is not a major problem in the tropics and subtropics, although water erosion can be. Little planting is done for water erosion control alone but its effects can be negated by wise land use, maintaining plant cover whenever possible. Tree planting in the tropics provides similar benefits to windbreak planting elsewhere in the world. Instead of regimented lines, protection is achieved by sporadic planting, a mix of species and uneven age classes. This is a form of agroforestry, combining trees with crops and animals. The advantages of agroforestry are being recognized and promoted to improve tropical land use but further research is needed. A brief summary is presented of the main genera planted and being considered for planting. These are _Acacia_, _Albizia_, _Caliandra_, _Eucalyptus_, _Gliricidia_, _Gmelina_, _Leucaena_, _Prosopis_ and _Sesbania_.

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BENEFITS OF WINDBREAKS TO ORCHARD AND VINEYARD CROPS

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ABSTRACT

Windbreaks provide protection to orchards during most of the year. However, there are some very critical periods when the shelter provided by windbreaks is the most beneficial. Two very important times are during the time the orchard is in bloom and during the period just before harvest.

Windbreak protection during the bloom period aids in pollination and in some cases protection from frost. This can have a significant effect on management options and decisions.

The protected environment provided by windbreaks prior to harvest can bring significant economic benefits in terms of fruit quality and quantity of fruit harvested.

During the other portions of the year windbreaks help to prevent deformation of the trees, reduce the amount of permanent tree staking, aid in proper limb scaffold development, provide an environment for the timely application of sprays and other maintenance operations. They also provide an environment where trees can grow faster.

From the standpoint of orchard maintenance and economics, windbreaks pay and are an integral part of good orchard management.

SHELTERBELT PLANTINGS IN SEMI-ARID AREAS

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ABSTRACT

The semi-arid lands of the world are characterized by low and often unreliable rainfall, with lack of soil moisture during all or part of the year being the predominant limitation to agricultural production and to other vegetative growth.

Throughout the world, these lands are often quite fragile systems, where agriculture is frequently a marginal economic prospect. Yet the pressure to expand agricultural production in these areas is increasing rapidly, and the results of imprudent expansion are often quite damaging to the long-term productive capacity of the land.

There are a number of particular land and soil problems which may cause difficulties in tree establishment, including soil erosion, salinity, unfavourable soil types and nutrient deficiencies. In many cases, these problems may be the result of the removal of native tree or shrub cover, and may be overcome in whole or in part by the re-establishment of trees in shelterbelts, woodlots or other formations.

While the major potential value of shelterbelts lies in allowing crops and pastures to make more effective use of the limited supplies of soil moisture, it is unusual in semi-arid farming to find any systematic provision of farm shelter for this purpose. With farming in these areas often a marginal prospect, there is little establishment of trees for the general economic benefit of shelterbelts and most farm shelter is established to counter very specific, limited and obvious problems. One of the reasons for the limited investment in properly planned farm shelter systems is that there is a very evident lack of quantitative cost/benefit information available relating to farm shelter establishment in either irrigated or dryland farming in semi-arid areas.

Establishment requirements for shelterbelts in semi-arid areas are similar to those encountered everywhere, with a general need for good site preparation, effective control of competing weed and grass growth before and after planting, and protection of plants from domesticated stock and vermin. The limitations of available moisture in this zone requires special importance to be attached to plant/water relationships at the time of establishment. Consideration should be given to supplementary watering, by hand methods, or by establishing irrigation systems, including drip or trickle irrigation. Tree establishment methods which may be considered include hand- and machine-planting, as well as direct seeding and natural regeneration.

The long-term survival and effectiveness of shelterbelts in semi-arid areas depends on proper establishment, good layouts and careful choice of species. It is evident from reports published that there is a common range of species used in many parts of the world, including in particular, species of the genera Acacia, Casuarina, Eucalyptus, Leucaena, Pinus, Prosopis, and Tamarix. A number of individual species are listed and classified for locality and primary uses. Indigenous species should always, however, be the first to be considered in any planting project.

The need for planting of new shelterbelts in semi-arid agricultural areas could be reduced if proper land use planning is applied during the initial development phase of the farmland. Much of the shelterbelt planting in these areas is required to redress particular problems arising from unwise clearing of native vegetation. Frequently, these problems, especially erosion and salinity, could have been avoided if the nature of the land was given proper consideration prior to development, and native tree or shrub cover retained and managed in sensitive localities. The most effective and economical land protection will, in the long term, be provided through proper land use, with the integration of forest or woodland management with agricultural production.

PLANTING AND ESTABLISHMENT OF WINDBREAKS IN ARID AREAS

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ABSTRACT

Extremes of temperature, low and erratic rainfall, strong hot and cold winds, high evapotranspiration, loose sand in the coastal and inland deserts, reduced soil productivity, low harvests, dearth of fuel-wood, fodder and shelter and generally poor socio-economic conditions make up the usual scenario of arid and semi-arid lands. The problem is so vast, diverse and challenging that no amount of modern knowledge of physical sciences and inputs would be able to change the landscape in the foreseeable future. If it were possible, the USA, the USSR, and several other advanced countries would have been able to harness nature by now. Large scale afforestation effort made by the Gulf States in the recent past bears testimony to the fact that an immediate answer to reclaim the deserts lies in planting trees and shrubs either in the form of windbreaks, shelter-belts or block plantations. These belts planted almost all over the world are not only meant to protect the agricultural fields and orchards from vagaries of the nature but also serve an important purpose, especially in the developing countries, of providing wood for local consumption by the rural population.

Additionally, the immense benefits of these belts in keeping the vast canal system running by serving as a barrier against siltation from wind blown soil and in better management of communication systems such as roads and railway lines in the deserts, have been fully recognized. This is especially true in countries like Pakistan, where more than 80% of the land mass is categorized as arid and semi-arid. No doubt, the tree rows in the arid areas are playing a very important role in combating desertification, retarding wind velocity, preventing wind erosion and improving crop yields through amelioration of the micro-climate. There is a tremendous improvement in the otherwise dull, dreary and drab landscape. All these factors significantly contribute towards making the life of local human and cattle population less miserable.

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THE STATE OF KNOWLEDGE ON WINDBREAKS IN THE NEAR EAST

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Introduction

The Near East, consisting of mountains, plateaus, and deserts, is characterized by contrasts. The Mediterranean climate of the north and the wet Monsoons of the south contribute to the wide range of aridity that exists throughout the region. Ninety percent of the Near East receives less than 400 mm annual rainfall. When it occurs, the rainfall is concentrated in the winter. Annual evapotranspiration rates of 2,500 mm and shallow soils (which frequently become salinized or water logged) contribute to the conditions of sparse vegetation, mostly shrubs. Land and resource abuse has led to land degradation, often desertification, in areas. To reverse this trend and, when possible, to improve site productivity, windbreaks have been established.

Objectives of Windbreaks

Windbreaks are planted in the Near East to protect farms, pastures, and other man-made establishment from wind erosion and desert encroachment, by acting as a buffer between marginal and cultivated lands; to improve the productivity of a site through improvements in the water budget; and to provide forest products (such as lumber, posts and poles, and fuelwood) and other commodities.

Where established, relatively narrow windbreaks of 1 to 2 rows are most commonly found around agricultural fields and orchards.

Choice of Species

Tree and shrub species are selected for windbreaks on the basis of drought tolerance, heat and salt resistance, and wind firmness. Tree species planted in the region include *Acacia* spp., *Albizzia lebbek*, *Casuarina equisetifolia*, *Cupressus* spp., *Eucalyptus cammaldulensis*, *Gleditsia triacanthos*, *Parkinsonia aculeata*, *Pinus* spp., *Prosopis juliflora*, *Robinea pseudoacacia*, and *Tamarix* spp. Shrubs, including *Ficus carica*, *Nerium oleander*, *Punica granatum*, *Ricinus communis*, and *Ziziphus* spp., are also widely used.

In extremely arid environments, *Eleagnus angustifolia* and *Tamarix aphylla*, utilized as fodder by livestock, are planted around orchards and farms. When windbreaks are established in irrigated areas, they mostly consist of *Populus* spp., in Jordan, Iraq, and Syria, and *Casuarina* spp. and *Eucalyptus* spp., in Egypt. Aggressive trees and shrubs with large crowns are generally avoided.

Site Preparation

Site preparation methods in the Near East vary with the climatic and

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edaphic conditions of the locality and the planting materials. Where feasible, mechanical site preparation with heavy equipment is undertaken. On steep slopes, terraces and countour strips are structured, while planting pits are dug to "harvest" water on level terrain. To increase the water capacity of the soil, subsoiling is often practiced.

Planting Techniques

In general, containerized seedlings, grown in state-managed nurseries, are freely distributed or sold to farmers. Like site preparation, planting techniques differ in the countries of the region. In Syria and Jordan, one-year-old seedlings are planted in pits or ditches at intervals of 30 to 150 cm between plants and 30 to 250 cm between rows. Windbreaks in Libya, planted to stablize sand dunes, are established in pits at 2 m intervals, with 2 to 3 rows in a windbreak. In the southern part of the region (for example, in Saudi Arabia), where windbreaks function to lessen blowing sand and prevent sand dune movement, cuttings from Tamarix spp. are planted at intervals of 4 to 6 m between plants; seedlings established from seed are also planted, although this practice requires supplementary watering. Trees and shrubs are planted at intervals of 2 m in 8 to 10 rows around farms and sand dune edges in the Sudan.

Planting is usually done in the winter by students, members of youth organizations, and factory workers. Some planting is undertaken by trained workers hired on a permanent basis. Forestry technicians and agricultural engineers supervise the planting task.

Cultural Treatments

With the exception of watering, virtually no cultural treatments of windbreaks are practiced in the Near East. Seedings are usually watered 5 to 6 times a year, up to 2 to 4 years after planting. Some windbreaks are irrigated with water transported by tanks or from local wells. In the Gulf States, drip irrigation is frequently used to water "Ghaf" and "Sidr" seedlings, which are planted in windbreaks around date gardens. Occasionally, the windbreaks are fenced and guarded.

Exploitation of Products

Trees and shrubs in windbreaks are a source of wood products and other commodities. Farmers cut stems for poles, housing materials, and other primary wood products. Branches are utilized as fuelwood, and leaves provide fodder for grazing animals. Oils, gums, and resins are extracted from some trees and shrubs, such as Acacia senegal, Pinus brutia, etc.

The Future

Interest in windbreak plantings has increased in the Near East, as governments become more concerned with environmental protection. Currently, extensive afforestation programs, including the establishment of "greenbelts" around settlements, are underway in the region. Additionally, windbreaks are being planted to improve the level of production in agricultural fields and orchards. Windbreaks are also recognized as a source of income and employment for local inhabitants.

A SHELTERBELT PROJECT IN ARID ZONE, LIBYA

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In 1981, a group of Danish engineering firms implemented the unprecedented largest agricultural project abroad, i.e. Danfarm in Libya.

The project has been paid by the Libyan government, and when fully established, it will produce 5.0 mill. broilers per year and have a livestock of 600 milking cows.

The roughage for the cattle will be produced on the farm. Both the fields as well as the buildings should be protected by means of shelterbelts.

When projecting the plantations it soon became clear that water was an article in short supply during the initial phase. It was, therefore, important to design the shelterbelts in such a way that the consumption of water, which should be applied manually, was as small as possible.

The farm is situated in an area with 100-200 mm of natural precipitation, with very high temperatures during the summer.

The soil contains approx. 15% clay and has good water-retaining capacity and good capillary quality.

In order to secure the plantation--corresponding to 135 km of single-rowed hedge--a trial planting was carried out in February 1983, using the following tree species: Acacia horrida, Acacia cyanophylla, Casuarina equisetifolia, Cupressus sempervirens, Eucalyptus camaldulensis, Eucalyptus gomphocephala, and Tamarix aphylla.

The reason for selecting these species was that they could normally be procured from local nurseries. The first 6 as plants, the last as cuttings.

The purpose of the trial was to test the minimum quantity of water necessary for the trees to survive.

The trees were planted in 4 x 4 blocks with 5 trees in each block.

All the trees were irrigated with 10 l on the day of planting and with 10 l one week later.

Then the irrigation was divided in 4 blocks:

1 block--no more water
1 block--water once a month
1 block--water once every fortnight
1 block--once a week

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The above irrigation system was carried through during the summer, and in October 1982, the results of the trial were assessed.

<u>% of Surviving Species</u>:

	no water		1 x water <u>/month</u>	2 x water <u>/month</u>	4 x water <u>/month</u>
Acacia cyanophylla	84		94	94	100
Acacia horrida	66		96	100	96
Casuarina equisetifolia	30		60	90	90
Cupressus senper-virens	44		56	70	86
Eucalyptus camaldulensis	36		54	60	90
Eucalyptus gomphocephala	50		36	60	100
<u>Tamarix aphylla</u>	<u>6</u>	<u>36</u>		<u>46</u>	<u>86</u>
Total	46	62		74	92

The results of the trial were used to determine the amount of water necessary for the individual species, because the client wanted all the species planted and a survival minimum of 80%.

The trial was continued another year on half the plots in order to evaluate how soon the irrigation could be ceased.

In 1985 the farm was finished. The shelterbelts had been planted and production of milk and broilers started.

PLANTING AND ESTABLISHMENT OF WINDBREAKS IN DENMARK

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The Shelterbelt Section of Hedeselskabet is a special organization with the main object of planting collective shelterbelts with subsidies from the Danish Ministry of Agriculture.

The section is organized with 18 consultants spread all over the country, and it is the only organization which plants shelterbelts with state subsidies.

On basis of amounts on the annual Budget it is possible to establish about 900 km of new shelterbelts each year.

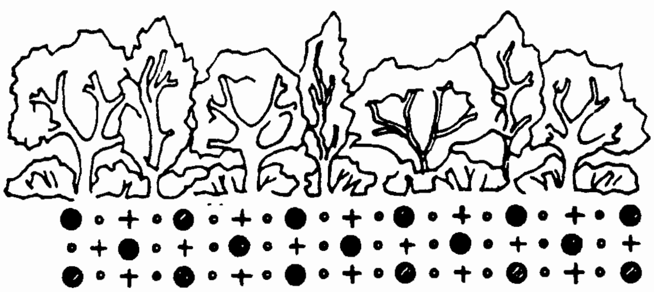
The primary aim of the hedges is to reduce soil erosion and to increase the crop yield. This planting work has been carried out during more than 100 years using various methods. In former days, only conifer hedges were planted, but from 1968 the amount of deciduous trees has been increased so that today only 3-rowed shelterbelts of mixed deciduous trees are planted.

The work is carried out on contract and is distributed on about 1600 plot owners a year. To reduce the costs, hedges are planted in one region (f.ex. a parish or a municipality) at a time, where at least 40 km of shelterbelts can be established. We aim at offering each plot owner a shelterbelt planting every 6th-10th year.

The work comprises felling and squeezing of old hedges, soil preparation, plants and planting work, cleaning for 3 years, and re-planting.

The work is carried out at a firm price. All plot owners pay the same amount for plants without regard to soil type or amount of hedges.

The main principle in the construction of the hedges is shown below:



Durable hedge of deciduous trees with a mixed tree stand.

Simplified diagram

● Permanent shelter trees + Nurse trees • Bushes

Row interval is 1.25 m.
Plant interval is 1.0 m.

Three kinds of crop trees are always planted--one is always oak--others are maple, elm, ash, cherry, and beech.

Among the bushes, hawthorn and lilac are dominating in the wind row. Crab, honeysuckle, snowy mespilus, and roses are common in the shelter row, and in the middle row grey willow and alpine currant are common. Grey and black alder are used as nurse trees.

There are always at least 14 species planted in a hedge. In total more than 50 species are used. The variation of species in the hedges are decided by the consultant.

Cleaning is a very important factor as to the success of the new shelterbelts, as this work has been a relief for the farmers and secures the durability of the hedges. In the first and second year after planting, mechanical cleaning is carried out 4-5 times, and manual cleaning 2-3 times. In the third year, chemical weed agents are being used.

This type of windbreak is being so common in the Danish landscape that it is a natural thing to provide for other landscape-consumers such as hunters, bee-keepers, and tourists. This means that we are planting tree species and bushes which serve a twofold purpose.

A very important factor in the establishment of windbreaks is the choice of the real origin.

By mixing of special tree species and bushes and hedges can be used as pure environmental plantings in cities and in industrial areas.

Today the hedges are so highly esteemed that they are considered Danish agriculture's most positive contribution to the environment.

THE POPULARLY ELECTED STRUCTURE OF SHELTER BELT PLANTING (SBP) IN DENMARK

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Shelter belt planting in Denmark has been done on a collective basis. It has always taken place in co-operation between the authorities and popularly elected organizations.

It has been the main task for these organizations to supply information and administer on the local level. The organizations have tried to influence both local and national politicians. Therefore, there has always been a reasonable support for legislation concerning shelter belt planting.

The first shelter belt associations were established in 1881 with the purpose of informing the farmers of the advantages of planting shelter belts around buildings and fields in order to improve the climate and the growing conditions.

From 1902, there has been a nation-wide organization with the purpose of encouraging SBP.

The official legislation has often been formed in such a way that these organizations have been referred to in the law and therefore they have been given certain authority.

1. Today the land-owners receive state-subsidy in two ways:

   a. 50% subsidy for purchase of plants for the landowner who plants himself.

   The subsidy is administrated through the local shelter belt planting associations who collect orders, arrange purchase and transportation.

   b. 50% subsidy to costs for the SBP cooperation who has their shelter belts established through Hedeselskabet (Danish Land Development Service-DLDS).

   The work consists of felling of old hedges, digging, planting and maintenance for 3 years. The land-owners become a member in order to have the shelter belt planted.

   These two organizations cover areas corresponding to 1/2-3 boroughs.

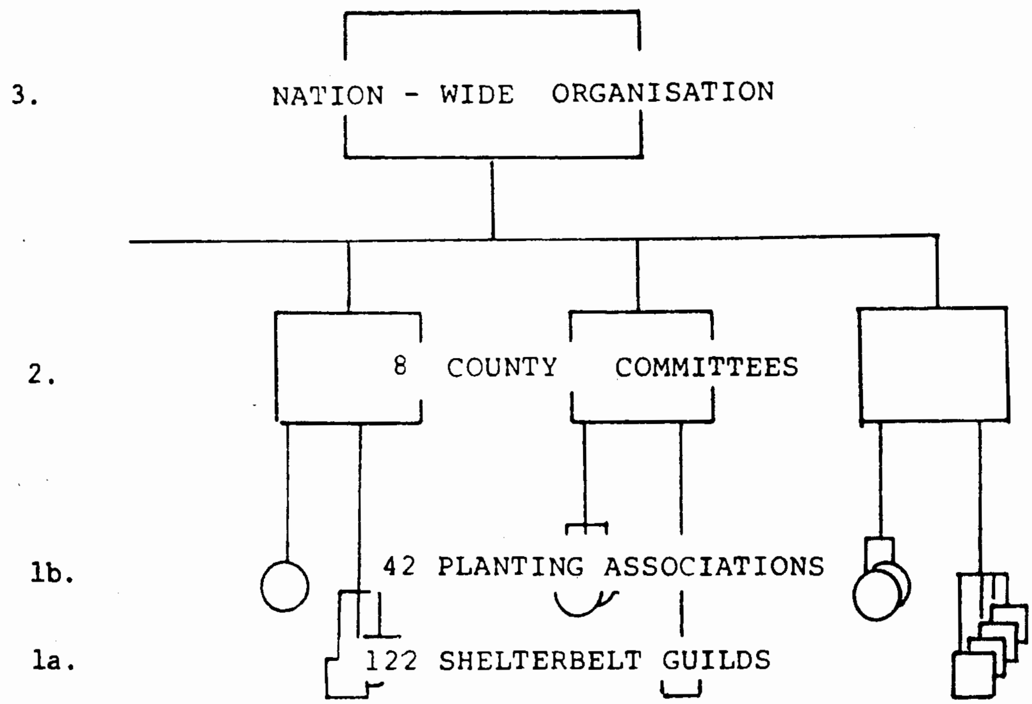
2. On a county level organizations are established gathering both the above mentioned and representatives from the Farmers Union.

The purpose of these committees are:

- to coordinate all SBP interests in the region
- to distribute information about the SBP in the region
- to ensure a fair distribution of the subsidy in the area
- to start up planting associations and guilds where these are not already established

3. On a nation-wide level all the chairmen of the regions form together with the representatives from the Farmers Union and Hedeselskabet (DLDS) a nation-wide organization. The purpose of this is:

- to gather all interests in one nation-wide organization
- to arrange nation-wide meetings in order to discuss questions of SBP
- to attend to political tasks on a national basis
- to consult and evaluate questions of a technical nature
- to coordinate information



RESPONSE OF WINTER WHEAT TO SHELTER IN EASTERN NEBRASKA

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Windbreaks, long considered important in the Great Plains for reducing soil erosion, also produce tangible but variable effects on crop yields. In the case of small grains substantial benefits have been reported by Stoeckeler (1962), Pelton (1967), Staple and Lehane (1955) and Brandle et al. (1984). In contrast, other research indicates no consistent trends in benefits to small grains (George, 1959; Frank et al. 1976; and Skidmore et al., 1974).

In 1964, six 40-acre windbreak systems and four 4-acre isolated unprotected checkplots were established at the Agricultural Research and Development Center near Mead, Nebraska. Since 1965 winter wheat has been grown in at least two of these systems for 16 of the 20 years. Prior to 1972 no significant differences in yield between sheltered and exposed plots were observed. For the period 1973 - 1975 no wheat was grown. In 1976 wheat was again harvested and for the period 1976 through 1982 average yields in sheltered areas were 14.6% greater than exposed areas. Yields varied from an increase of 50% in sheltered areas in 1981 to a decrease of 44% in 1982 (Brandle et al. 1984). In 1983 wheat yields were reduced by 7.2% in sheltered areas but were increased by 128% in 1984.

Economic consequences have been fully discussed in previous publications (Brandle et al. 1982; Brandle et al. 1984). Explanations as to the causes of these yield responses are lacking. In this paper I would like to offer, for discussion, a hypothesis which could explain the variablility between years in yield response.

Windbreaks tend to moderate the extremes of cold, dry, windy conditions, and/or hot, dry, windy conditions. In years when these conditions are most prevalent, windbreaks have their greatest effect.

For example, during the years 1976 - 1984 wheat yield increases due to shelter were greatest for those years in which average winter temperatures (November - March) were below normal (1977, 1979, 1984). The incidence of winter kill in wheat was greater in exposed areas than in sheltered areas. For years in which yield increases were small or negative (1976, 1980, 1982, 1983), average winter temperatures (November - March) were near normal or above and no differences in the incidence of winter kill were observed between sheltered and exposed areas.

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However, there are exceptions. In 1982, when yields in sheltered areas were reduced by 44%, eastern Nebraska experienced the first significant outbreak of wheat scab since 1951. The cool, wet weather of May and June, coupled with the earlier maturity date of shelter-grown crops led to an increase in the incidence of disease in sheltered areas and resulted in reduced yields (Boosalis et al. 1983).

Windbreaks tend to moderate weather extremes. However, changes in the microclimate of sheltered areas can have both positive and negative effects depending on the crop and/or even the particular variety. It is imperative that we recognize the microclimate response and select crops and/or varieties that utilize these changes to the advantage of the producer. Overall, windbreaks reduce the producer's exposure to risk and result in higher average yields over the long term.

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LANDSCAPE ROUGHNESS AND SHELTER

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Research on shelter effect has concentrated largely on individual windbreaks or small series of parallel barriers. Their collective contribution to terrain roughness, in association with other landscape features (hedgerows, small woodlands, etc.), has been relatively, but not entirely, neglected. At a time when agricultural landscapes throughout the developed world are becoming more open, as traditional field patterns disappear and hedgerows and shelterbelts are in decline, it would seem opportune to consider sheltering features and their influence on surface winds on a district or regional scale. To quote from an earlier paper (Caborn 1976), there may be a need to maintain the overall roughness of the countryside "even if this means replanting hedgerows and tree plantations previously uprooted in the name of economy" (McIntosh & Thom 1969).

Although more sophisticated theoretical treatment of the individual belt (e.g. Plate, 1971) and parallel belts (Seguin 1973, Seguin & Gignoux 1974, Iqbal et al. 1977) has appeared since, van Eimern et al.'s (1964) comprehensive review of the first 50 years of shelterbelt research showed conclusively that the shelter afforded by a windbreak depends on certain physical attributes of the barrier (height, porosity, etc.) and on the direction and nature of the incident wind. "Nature" here includes airflow modifications arising from thermal and mechanical influences, i.e. temperature stratification of the air and terrain roughness upwind, respectively. Whereas a single windbreak in the open provokes only a transitory disturbance of the wind-field, in an extensive system the wind adjusts to a new equilibrium dependent on a changed surface roughness. Each successive windbreak contributes to overall roughness and determines to some extent the effectiveness of further barriers downwind.

Areal values of roughness, in terms of the roughness parameter, z_o, are freely available in micrometeorological literature, at least for homogeneous surfaces, although their appropriateness for forest vegetation is often in doubt. Mean regional values are derived frequently and Garratt (1977a & b) has mapped the Australian sub-continent using 30 vegetation classes and z_o values for modelling the surface's contribution to synoptic scale disturbances. With non-homogeneous surfaces the problem becomes one of spaced roughness elements. Sutton (1953) suggested that roughness would be most influenced by the mean height of roughness elements and their mean distances apart. Based on Kutzbach's (1961) bushel basket experiments on the ice of Lake Mendota, Lettau (1969) proposed a simple empirical formula for roughness length determination. He tested this with some success in separating the roughness due to the grass cover and that due to instrument masts in the Davis experimental field. Since that time, roughness arrays of varying density and distribution have attracted wind-tunnel and field experiments (Marshall 1970, 1971, Counihan 1971, Seguin 1973, Wooding et al. 1973, Seguin & Gignoux 1974, Arya 1975, Iqbal et al. 1977). This research is closely related to similar studies of airflow over vegetation canopies (e.g. Seginer 1974) and Businger (1975) combines both in his discussion of parametrical representation of roughness.

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The practical applicability of such theoretical developments is of paramount importance. Marshall (1970) aimed at an assessment of the optimum shrub cover for erodible rangeland. Seguin (1973) demonstrated the influence of a system of parallel windbreaks on regional roughness and, thence, on the aerodynamic term, E_a, of Penman's formula for evapotranspiration. Similarly, Chiapale (1975) modelled heat budget modification introduced by a system of hedges. It is pertinent to reflect that the principle of spaced roughness elements is involved in many traditional practices, e.g. universally adopted techniques for stabilising dune sands and mine tailings, stubble mulches, etc., where the objective is to increase surface drag. Scales may differ but common principles apply. Admittedly, conceptual difficulties remain unresolved, e.g. to what extent are roughnesses additive, considering the continual development and decay of internal boundary layers around obsticles? Also, at what interval between roughness elements does the zero plane displacement, D, come into play? Further, what types of field data are most urgently needed?

The future is challenging but, gradually, a theory is emerging which, hopefully, will lead to a realistic quantitative evaluation of the roughness afforded by extensive windbreak systems, the possible consequences of drastic change and the implications for surface wind forces and heat and water balance. There could be a critical terrain roughness which, in windy climates, should not be sacrificed arbitrarily.

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PRINCIPLE AND EFFICACY FOR THE ESTABLISHMENT OF WINDBREAK SYSTEMS IN OASES OF XINJIANG DESERT, CHINA

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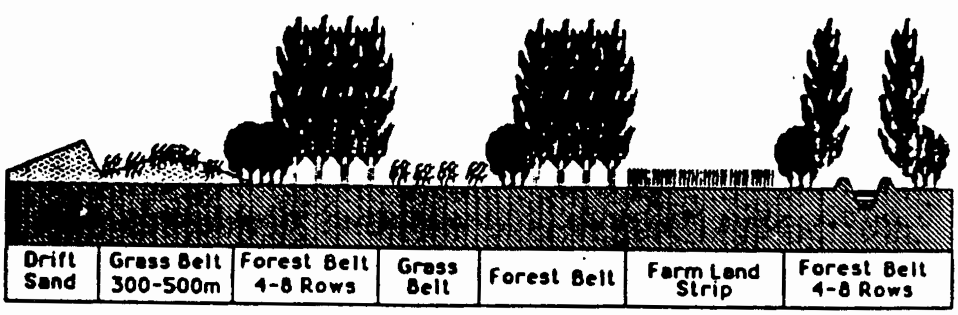
"Protective Forest system" is an efficient natural-artificial entity and also a scientific conception. It is produced by long-term productive practice and scientific research in desert zone of Xinjiang - the eastern Central Asia (Ci et al. 1980). The field observation of Section of Protective Forest, Xinjiang Institute of Forestry with complements of wind tunnel simulation experiments (Lanzhou Institute of Sand Desert, Shenyan Institute of Forestry and Soil, Xinjiang Institute of Forestry, and August 1st Agricultural College 1978) indicate that the establishment of the overall protective forest system in which the "narrow belt and small network of windbreak" is the core of the system, is a fundamental measure for creating and maintaining the high productive oasis ecosystem in Xinjiang desert. The protective forest system not only ensures and increases the production of crops efficiently but also greatly improves the living environment for the human beings in desert area.

1. Composition and principle of the windbreak system: The windbreak system is composed of: (1) Sand stabilizing grass and/or shrub belts on the fringes of oases, (2) Sand-controlling forest belts, and (3) Field-protective forest networks. Together these form a system combining forest belts, shrub and/or grass belts, and crop strips to maintain the environment and its balance of the oasis ecosystem. The windbreak system transforms or converts unused energy and waste water into effective biomass, weaken or check harmful energy (strong winds, high temperatures, etc.), regulates microclimate or local climate, accelerate nutrient circulation in the soil so that organic matters may be replenished (See Figure 1).

Figure 1



Schematic Diagram of Wind-break & Sand Protecting
(Tree, Shrub, & Grass) Belt System

2. Protective Effect of the windbreak System: According to the long-term field observations and laboratory simulation experiments with wind tunnels, the protective effect of windbreak systems basically depend on not only the total amount of wind velocity reduction, but also the size and velocity of downward transferred momentum from upper air flow on the leeward side of forest belts.

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(1) Windbreak effect of forest belt systems: it is decided by the structure and shape of transverse section, and the wind-permeability coefficent of forest belts. There are 4 structured types of windbreak belts that have been researched in the field and laboratory. The effect of the various windbreaks on wind velocity is shown in Figure 2:

a. Dense structured forest belt
b. Thin structured forest belt
c. High ventilation structured forest belt
d. Low ventilation structured forest belt

According to our research, the windbreak systems with "narrow forest belts and small grids" have the best protective efficacy and have been widely adopted in Xinjiang.

The field observations and wind tunnel experiments indicate that the thin structured and low ventilation structured belt with transmissivity of 0.5 has the optimum effect on reducing air flow (Fig. 2) and is also best suited for the growth of trees. It is a double crowned forest belt. The average wind velocity within 1-20H in the leeward side of the belt is reduced to 41%. The interval between main windbreak belts is 300 m instead of the 500 m distance for usual windbreak systems.

Figure 2

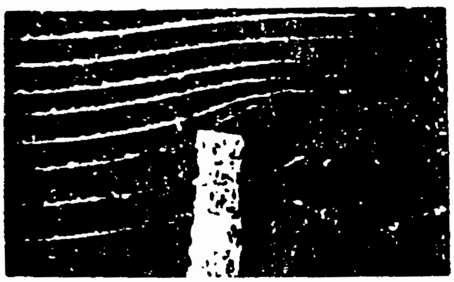
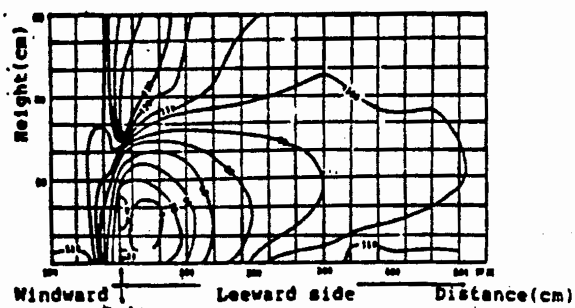
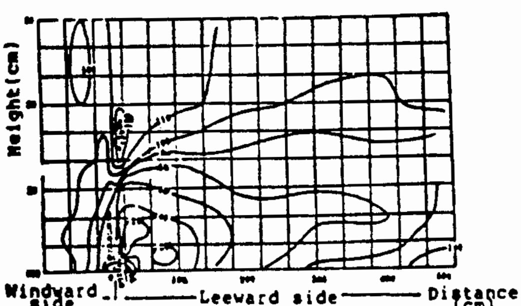


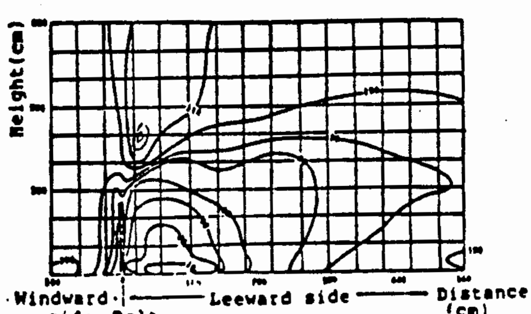
Fig.2 Spectrum of smoke flow for a thin structured model windbreak(beta=0.5)



Wind velocity field in a model forest belt with ventilating structure



wind velocity field in a model forest belt with dense structure



Wind field in a model forest belt with thin structure

THE IMPORTANCE OF SHELTERBELTS IN EGYPTIAN AGRICULTURE*

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Abstract:

Windbreaks and shelterbelts are vital components of agricultural and settlement schemes in Egypt generally, and in the desert regions particularly. _Casuarina_ spp. and _Eucalyptus camaldulensis_ are the most extensively used trees in establishing windbreaks. Relatively little research has been done on the effects of windbreaks on crop yields and climatic factors. This paper is intended to outline some of the activities related to windbreaks in Egypt.

Egypt is almost void of natural forests at present. Yet, introduction of exotic trees has been practiced for a very long time. There is a complete integration between agriculture and forestry in Egypt. Trees and shrubs are grown primarily as windbreaks and shelterbelts around cultivated fields, along canals and roads, as well as on farmsteads. The Egyptian farmer seldom leaves a spot that can support a tree without planting. The area of line plantations is estimated at 100,000 acres out of the 5.5 million acres of cultivated area. The network of windbreaks is perhaps the most extensive and elaborate system of its kind in the arid regions of the world.

The need for shelterbelts is particularly felt in the new land which is located on the desert fringes. Egypt is exposed to very severe winds, mainly during late spring and early summer. The harmful physical and physiological effects of sand storms and desiccating winds are very well known in the country. The new communities under development in the desert require good protection as well. Trees and shrubs are also used for sand dune stabilization.

The species used as windbreaks in Egypt are mainly members of the genera _Eucalyptus_ and _Casuarina_. _E. camaldulensis_ represents nearly 20% of windbreaks in Egypt while _C. glauca_ and _C. cunninghamiana_ represent over 70%. _C. equisetifolia_ is planted on the coast as it tolerates salt spray. The other two casuarina species are planted in land. _C. cunninghamiana_ is restricted to good-fertile soil and fresh water coures, while _C. glauca_ is planted in more difficult sites, such as water-logged, saline or calcareous soils. It also tolerates brackish water irrigation.

A casuarina breeding programme aiming at producing genetically improved material to be planted as windbreaks and in wood lots has been underway for the past 10 years, (El-Lakany, 1983). Very little research work has been done on the physical and biological effects of windbreaks in Egypt. Also the design, composition and orientation of windbreaks have received very little attention. Nevertheless, some quantitative research has demonstrated the beneficial effects of windbreaks.

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Hussein (1969) found out that the yield of sheltered fields of cotton, wheat, maize, and rice increased by 36, 38, 47 and 10% over the unprotected fields, respectively. The favourable effects of windbreaks were demonstrated by El-Sayed (1969). The response varied according to windbreaks composition, and orientation and the type of crop. The yield of wheat, maize and clover increased gradually from the belt to reach a maximum at a distance of 3-4 H. In sheltered citrus, early fruit ripening, thinner peel, low acidity, and high total soluble solids and vitamin C, hence improved fruit quality, were noted. The unfavourable effects of windbreaks included root competition and shading.

Again, working in Northwestern Egypt, Khalil (1982), concluded that the yields of wheat, barley and corn were affected mainly by the orientation of the windbreaks. The extent of the protected area was proportional to tree height, and the sheltered fields yielded significantly more crops than unsheltered ones. In general, the yields decreased at a distance of 1/2-1 H, then increased gradually until they reached maxima at 6-10 H. At a distance of 15 H or more, the yield of sheltered fields did not differ significantly from that obtained in the open (unsheltered) fields.

Research work in progress at the Desert Development Center of the American University in Cairo deals with the selection of suitable species and provenances, inter-belt competition among Ecalyptus and Casuarina species, different designs and testing of new species, such as Acacia salignas. Metreorological parameters and soil physical characteristics are being monitored inside and outside the existing belts.

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THE POTENTIAL EFFECT OF WINDBREAKS, BARRIERS AND RESIDUES ON THE DEVELOPMENT OF SMALL GRAIN PLANTS

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Development of small cereal grains has been researched by Betty Klepper, R. W. Rickman, and C. M. Peterson, of USDA, ARS, Columbia Plateau Agricultural Center, Pendleton, Oregon. They have identified a set pattern of development of unstressed plants based upon Growing Degree Days (GDD).

Growing Degree Days for grain is determined by adding maximum, plus minimum temperature in centigrade, and dividing by 2. Positive values are added together to determine GDD for each day. Under most Pacific Northwest planting conditions, it takes about 150 GDD for winter wheat to emerge. Leaf development takes about 90-100 GDD. Spring wheat, barley, and oats have a shorter period of about 70-75 GDD. The length of the biological GDD period is set with the growth of the first leaf, and continues at the same pace for leaf, tiller and root development. This period is known as a phyllochron.

Knowledge of the grain plant development pattern matched to average GDD, or to accumulated annual GDD identifies the potential plant development at any given time up til elongation begins. Grain plants in a field can be compared to GDD's time clock, and plants in one part of a field may be compared to those in another part of the field. Stress conditions affect leaf length, subtillers, and number of tillers. Windbreaks, barriers, and residue amounts, affect soil and air temperatures. The average GDD for plants downwind from barriers may be higher than for open fields. Knowing grain growth patterns can assist in the evaluation of wind barriers, residues, strips, and windbreaks.

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VEGETATIVE TREATMENT OF ABANDONED CROPLAND IN THE SONORAN DESERT TO REDUCE SOIL EROSION

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Introduction: There are approximately 100,000 acres of abandoned cropland subject to intermittent wind erosion in southern Arizona. Sudden summer windstorms may dislodge soil particles causing dust clouds that pollute the atmosphere and may reduce visibility to zero. Several multiple automobile accidents on Interstate Highways 8 and 10 have occurred.

The purpose of the planting was to: (1) define cultural techniques to concentrate run-off in borders to a seeded area, and (2) evaluate species for establishment. Combinations of these were used to make recommendations for erosion control on abandoned cropland.

Site Description: The planting site is located in the transition zone between the Lower Sonoran Desert Shrub and the Upper Sonoran Desert Shrub Region of Major Land Resource Area D40-1 and D40-2, at an elevation of 1,867 feet. Mohall clay loam dominates the site. They are characteristically deep, well drained, and slowly permeable soils. The pH at the site is 8.2 in the surface soil and soluble salts are 1,340 ppm. Frost-free days range from 250 to 350 days. The mean annual rainfall is 10 inches but may vary from 2 to 15 inches. The planting site is located 25 miles northwest of Tucson, Arizona, along Interstate Highway 10 at milepost 225.

Procedures: In 1977, two seeding mixtures and eleven cultural practices were installed on a 20-acre abandoned field.

In October, 1979, an adjoining 34-acre abandoned field was treated and seeded. The seeding mix (Table 1) and cultural treatments (Table 2) were selected from those that were successful in the original 20-acre planting. Contour borders were 50 and 100 feet apart. The lower portion of each border was ripped, contour furrowed or left as a control. Untreated areas between borders acted as a water collector to provide extra moisture for planted areas.

Results and Discussion: Full canopies developed on three of the twelve treatment areas (Table 2). Each treatment area was replicated. Best protection was provided where 28 and 42 feet between 100-foot contour borders were ripped and seeded.

T03553 fourwing saltbush was the only one of the seven species planted that provided adequate cover and size to be effective as a windbreak.

Planting recommendations for abandoned cropland in MLRA 40-1 and 40-2 in Arizona are:

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1. Install contour level border ridges every 60 feet. This is about 10 times the height (5 feet) of mature fourwing saltbush, plus the width of the strip.
2. Rip a strip above the berm 18 inches deep and 28 feet wide.
3. Drill the seed in a strip 12 feet wide directly above the berm.
4. Plant 5 PLS pounds of dewinged T03553* fourwing saltbush seed per acre.
5. Plant between October 20 and November 20.

*T03553 fourwing saltbush is not commercially available. It is in the Field Planting Program at the Tucson Plant Materials Center.

PLANTING AND ESTABLISHMENT OF WINDBREAKS ON CROPLANDS IN SEMI-ARID TROPICS

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As part of a Project sanctioned by the Ministry of Environment, Government of India in 1983, a length of 11 km. of windbreaks was raised during 1984 and 1985, in North Devadanam in Tamil Nadu state. The study area is in the leeward fringe of the Western Ghats in Ramanathapuram District. Abundant natural resources (water, soil and terrain) and subsistence level agriculture present a study in contrast. Soil drift caused by fierce (dominantly westerly) winds during July-September covers fields to a depth of 10 cm and in disastrous years like 1976, to 70-75 cm. Rather than fight the elements, the farmers leave the land fallow for the major part of the year. Research into a designed windbreak complex treating the entire affected area claims priority in the Project. A pilot-scale 200 m. long windbreak raised in 1976 after the severe hurricane in July-August that year stands out as a model barrier conferring a degree of protection to an enterprising farmer's land. In the light of the success of that first effort, this project for research into a windbreak complex treating the most vulnerable area of 192.10 ha. in the western extremity of village as one unit, was conceived. Virtually all the land is privately owned and the Project has set store by the passive cooperation of the self-cultivating small farmer landholders. The windbreaks are part of proprietory holdings. Windbreak alignment had to be flexible within limits and follow existing field boundaries inorder to avoid creating ownership problems later. The general direction and a distance of 80-120 m. between successive 5 m. wide tractor-ploughed belts were maintained. The problems met with in planting and establishment, the performance of different shrub and tree species, the observations of the effects on microclimate and crop yields and the proposals for the future are described. One lesson is clear viz. the relevance of forestry to agriculture cannot be brought home to a teeming population of small farmers except through its direct and demonstrable benefits for which windbreaks in cultivated land are a fine example.

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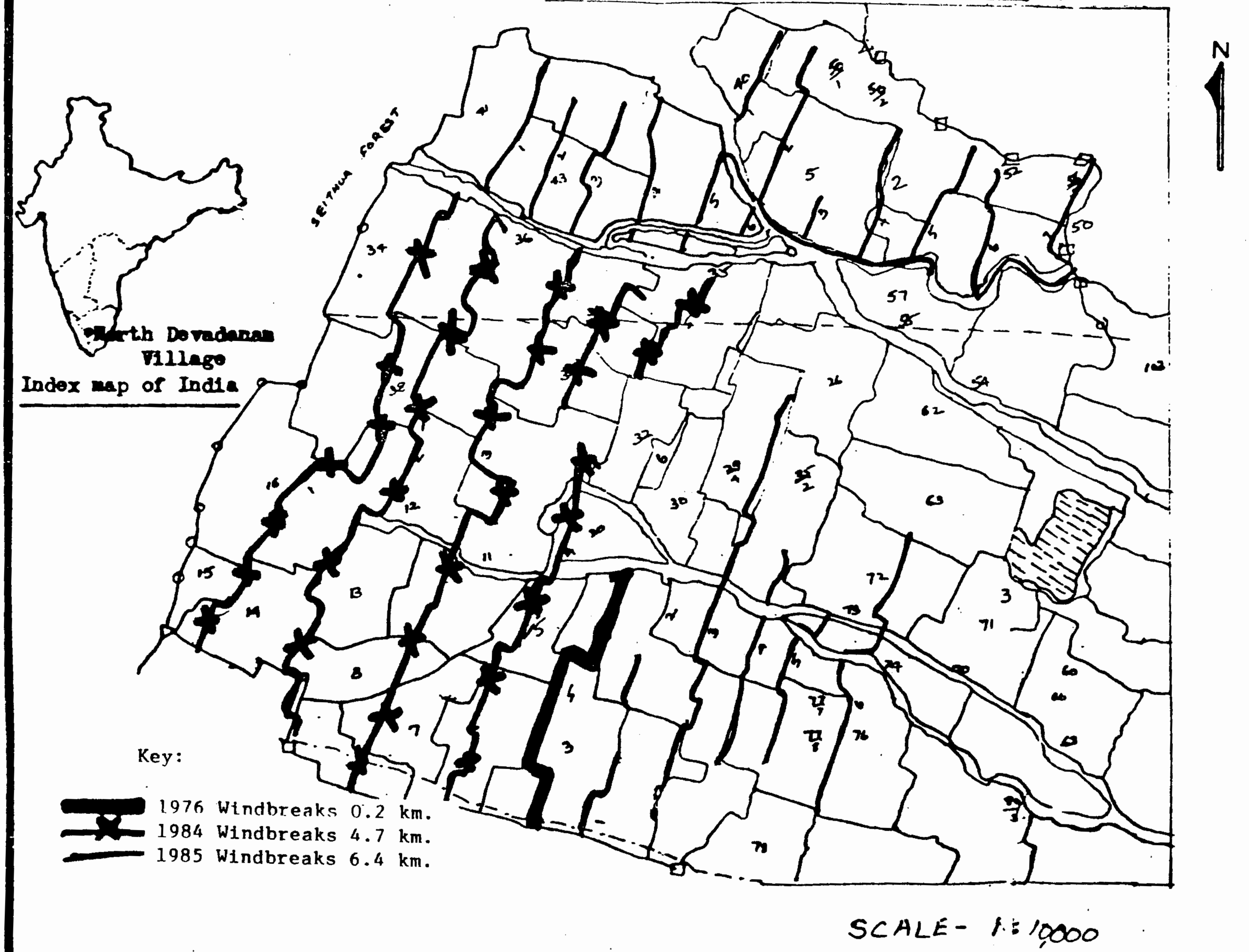
SKETCH SHOWING THE SHELTERBELTS RAISED IN NORTH DEVADANAM VILLAGE, RAJAPALAYAM TALUK, TAMILNADU STATE



THE ECOLOGICAL EFFECT AND ECONOMIC RESULT OF A JUJUBE-TREE-BELT--CROP SYSTEM IN NORTH CHINA PLAIN

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Abstract

Intercropping of crops, annual plants, with jujube tree, perennial plant, in some areas of North China Plain has a history longer than 400 years. Jujube trees are cultivated in a manner of parallel belts in the crop field. Each belt is composed of a single row generally, but of two rows in a few cases. The distance of spacing of two adjacent belts is around 15 m (10 to 20 m) in most of the fields with this intercropping system; the distance may be reduced to as less as 8 m in some other fields. But the spacing of trees in the rows is quite unique, viz about 3 m.

Owing to that the spacing distance (10-20 m) of jujube tree belts is much shorter than that of the common shelterbelt system (200-500 m) in North China Plain, the ecological effects, including the improvement of microclimate and soil moisture condition, increasing the period of filling of grains and the weight of grain and finally increasing the yield of crops, is more effective than that of the common shelterbelts (Table 1).

Table 1. The ecological effect of some typical jujube-tree-belt--crop system

Reducing the wind speed	to 50-70% of the open field
Keeping more soil moisture	by more than 25% of the open field in 0-30 cm zone of field
Reducing the frost damage of advective type of winter wheat	by 30-50% (if the frost damage occurred in that winter)
Reducing the loss of yield of wheat due to the damage of the "dry and hot" wind	by 10-20% (if the "dry and hot" wind prevails in that spring and early summer)
Lengthening the period of filling of grain of wheat	by 3-5 days
Increasing the weight of grain	by 2-3 mg per grain
Increasing the yield of wheat	by 6-15%.

The economic result of the jujube-tree-belt--crop system can be illustrated respresentatively by the increasing of the annual yields of cereals and dried fruit of jujube and income in cash of both these two products per person of Lishanzhuan Village in Xien County of Hobei Province which is considered as a typical model of this system (Table 2).

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Table 2. The economic result of a jujube-tree-belt--crop system of Lishanzhuan Village in Xien County of Hobei Province

Year	Total annual yield of ce- reals (ton) jujube (ton)	Ann. yield of dried fruit of (Chinese yuan)	Income in cash of both cereals and jujube*	Income in cash per (yuan)	% of area with this sys. to total
1965	66.2	11.6	1.8×10^4	36	27
1975	106.6	56.3	5.25×10^4	58	83
1976	92.9	33.1	5.47×10^4	57	
1977	--	13.5	0.65×10^4	--?	
1978	118.6	25.0	5.86×10^4	63	
1979	160.0	55.0	12.99×10^4	100	
1980	170.0	90.0	16.62×10^4	285	
1981	155.0	137.5	22.84×10^4	392	
1982	240.0	205.0	34.92×10^4	599	100
1984	270.0	250 0	53.25×10^4	845**	100

*Most cereals are distributed as grain ration, only a very small part of cereals is accounted for cash.

**The population of this village in 1984 is 630, and the area of field under cultivation is 71.3 hectares.

From Table 2, the income in cash per person of this village in 1984 is 845 Chinese yuans which is 23.5 times of that in 1965, and is about 14.5 times of that in 1975. Furthermore, the contribution of the income from the fruit of jujube per person is 794 yuans in 1984, i.e., it accounts for 94% of the annual income in cash per person.

A mathematical model is proposed by the author in order to get the optimal combination of jujube-tree-belt and cereal crops.

AN ANALYSIS OF SOILS SUITABLE FOR FORESTS IN NORTHEAST CHINA'S COASTAL SHELTERBELT AREA

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There are many complex sea shores in the Northeast Region of China.

Using edaphic conditions, where soil specificity, factors of soil formation, coastal land form, and parent rock, can effect the adaptability of trees, the sea shore can be divided into four coastal types:

a. Curved-low mountains-high abrupt coasts, which have sea erosion and are underlain with rock with thin layers of brown forest soil. Rocks are exposed at some places;

b. Rolling hills-low coasts, which have sea erosion, and thick layers of brown forest soil;

c. Flat-sandy shore, which is a regressional phase, with sandy soils sandy plaggen soils, and sandy meadow soils. There are also some arenaceous soils with high ground water tables but they drain well;

d. Flat muddy shore, which is also a regressional phase with saline marine meadow soils, thick layers of meadow soils and bog soils on lithoral deposits and broad alkali flats. The soils do not drain well and the ground water is always recharged by sea water.

The most adaptable sea shores for tree growth are b and c. The thick layers of brown forest soils, sandy meadow soils, sandy soils and some desalted soils are better for forests than the others. For instance, the fertility of the brown forest soil is fairly high since organic matter, total N and total P (P_2O_5) are fairly high. The growth of black locust on the deep brown forest soil is relatively good. The height and diameter growth are fairly good over the first ten years, average annual diameter growth is 0.75 to 1.8 cm; annual height growth is 0.95-2.4 meters.

Having estimated the growth of the main tree species of the sea shore shelterbelts, we know that black locust can grow better on deep brown forest soils but can't tolerate excessive moisture and imperfect drainage. It is more tolerant to salt than Populus. It can also grow vigorously on desalted soils and haploid halophyte soils with lowered ground water tables.

To improve the suitability of the saline soils, it must be drained to lower the water table and permit leaching. Methods such as building dykes, embankments, raised strips, etc. must be used. The change in salts can be seen from data taken from soil profiles. After desalting, the saline soil's salt content and that of moderately saline meadow soil are close. The chlorine salt content fell from 1.33% to 0.018%. The 8 year old black locust planted in desalted soils on raised strips was good, the tree height was 7-8 m, dbh was 8 cm with the largest reaching a dbh of 10 cm.

The <u>Populus</u> <u>canadensis</u> and <u>Populus</u> <u>nigra</u> Var. <u>italica</u> (Muench) Koehne X cathayna Rehd. can grow well in some arenaceous soil and sandy soils with excessive moisture. However, the sandy soils must drain perfectly.

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For instance, P. nigra V. italica (Muench) Koehne X cathayana Rehd grows rather well on the deep meadow soil. From the growth trends, it can be seen that in the first 6 years' of growth the annual height growth exceeds 1.5 m and average dbh increment is 1 cm. When the Canadian poplar are grown on sandy soils, it achieves better height and diameter growth. On such sites the Canada poplar has reached a height of 18.1 m, with an annual increment of 1.13 m; the dbh was 15.6 cm, with an annual increment 0.99 cm. The deep rooted poplar is not suitable for the thin soils or flood zones, but its root development on deep, loose, sandy soils is quite good.

SOME ASPECTS OF ESTABLISHMENT AND EFFECTS OF SHELTERBELT SYSTEMS IN NORTHERN CHINA

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The whole area of China can be divided into two areas according to differences in rainfall.

The shelterbelt systems of the three northern regions (north, northeast and northwest) are situated mainly west of the demarcation line.

Natural conditions are very severe, especially in regard to climate in this area. A very dry wind blows strongly over this region almost year-round. Wind damage often occurs in Spring and in the growing season, with a maximum wind velocity of more than 17 m/sec. It injures crops and causes shifting sands to move and cover grassland, farmland, roads and houses. The land is suffering desertification, desolation and decreasing grass and crop yields.

Initial success of shelterbelts has been achieved since the shelterbelts were planted in 1978. The forest cover has been brought up to 6% as of 1985 from the initial 4%.

We performed some research work for getting effects from planting pasture forests. Snow damage often occured on grassland. The livestock didn't have enough grass for food, but ever since fodder trees of the species Ulmus pumila has been planted, the leaves, twigs and shoots of that tree solved this problem. Thirty cows were fed by pruning trees for their leaves and branches before heavy snow storms, sometimes we can get 89,000 kg of material with nutrients and yield much higher than natural grass vegetation. The percentage of nutrients has been analyzed.

Because the shortage of water is so serious and hinders survival and growth of trees, the key to the success of afforestation lies in meeting plant water requirements. We did some work in this area in the western part of the northeast region.

First, we choose suitable trees for certain sites. As we know, the climate is quite continental. The more than 70% of the total rainfall is concentrated in the summer from June to August. The driest season is in Spring when the soil moisture and atmosphere humidity are both very low. So it is more important to choose suitable trees for certain sites in this area where there is a water shortage and there are different size and depths of calcic horizons beneath the ground surface in castonozems soil, and where it's often covered with different depths of sandy soil. The results of my research work showed that the Pinus sylvestris v. mongolia tree species is better than Populus pseudo simonii.

Because its strong root system has ability to penetrate this calcic horizon to reach the deep subsoil layer for getting more moisture, and its transpiration intensity is less than Populus spp. In the daytime during the growing season, the data showed that transpiration rates vary with soil types and differences become greater as the land become poorer.

Other shrubs and trees such as Caragana microphylla, Prunus sibirica, Caragana korshinskii, Lespedeza bicolor also can grow well in this area. They are all indigenous plants. Poplus spp. grow well on sandy soil and meadow black soil. So, shelterbelts have been planted on farmland using this species.

Second, we improve soil condition. Different techniques of site preparation vary with different site types and soils. Thus, we can retain more water, prevent water loss, and provide for better growth. For instance, the deep-pit and trench techniques are often used in semi-arid zone in western part of northeast Region on the sandy castonozems soil and sandy soil. The seedlings were planted on the bottom of trenches or pits to get more moisture from the soil and provide shade to decrease transpiration.

Third, we used special planting techniques. For instance, when four or five year-old seedlings of Pinus sylvestris v. mongolia with original soil clumps are planted on pastureland in Heilongjiang Province in the summer or fall instead of in the dry springtime, the survival rate is more than 96%. The results are much better than 2-year seedlings. But, nowadays, there are some problems there with tree growth because of the limited water resource in this area. So, the key problem is; how do we make both tree growth better and maintain the water balance? The most important tasks is to find the best spacing of plantation, optimal forest cover, and the proper disposition of shelterbelts in this area. Presently, we have designed a plan for getting better results using different planting formations. Many kinds of pasture forests have been established with belts of scattered trees instead of planting a large-scale plantation with close spacing.

ADAPTATION TRIALS OF EUCALYPTUS SPECIES
IN SOUTHERN ARIZONA AND SOUTHERN CALIFORNIA

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Introduction: Adaptation trials were begun in 1979 at the Soil Conservation Service--Tucson Plant Materials Center (TPMC) to evaluate *Eucalyptus* species--both trees and shrubs--for use in the arid southwest for windbreaks, shelterbelts, wildlife habitat, fuelwood, beautification, and erosion control. These species are primarily adapted for plantings in MLRAs 19, 20, 30, 31, 40 and possibly 41. Species were evaluated for drought resistance, cold hardiness, vigor, survival, heat tolerance, height and canopy diameter, leaf and seed production, ability to spread, and wildlife value. The main project is located at the Tucson PMC with other sites in southern Arizona and southern California.

Materials and Methods: The assembly of *Eucalyptus* seed, consisting of 125 species--a total of 136 accessions--was obtained from commercial sources, botanical gardens and the SCS National Plant Materials Center (NPMC). The adaptation trials at the Tucson PMC, known as intial evaluation plantings (IEP), were planted in 1979 and 1981.

Management of both IEPs was as similar as possible. Seedlings were grown in the same manner in 1979 and 1981. Pre-germination treatments were applied, cold stratification (40 °F) for three-four weeks. Seeds were planted in galvanized metal flats containing a 1:1 perlite:vermiculite soil mix with Osmocote 14-14-14 fertilizer added at the rate of 4 oz. per bushel of soil mix. Optimum greenhouse temperatures (65-75 °F) and humidity (20-40% RH) were maintained. As the seedlings developed true leaves, they were transplanted into bottomless 2-1/4x2-1/4x6-inch plastic containers. The soil mix consisted of 1:1 milled peat moss:sand and Osmocote 14-14-14 fertilizer. After an eight-week establishment period, the seedlings were moved to one-gallon cans containing 1:2 loam soil:decomposed bark mix plus Osmocote. The plants were then taken from the greenhouse and placed in a "lathhouse" for a minimum three-week hardening-off period. Plants were watered once a day for two minutes by overhead sprinklers.

Plants were transplanted in the field on March 26 and June 18, 1979 and on April 4, 1981. Soils are Grabe loam and Comoro fine sandy loam. Fields were laser leveled, ripped and pre-irrigated prior to transplanting. The 1979 planting was made in furrows, while the 1981 IEP was planted on flat--less than 0.1 percent slope--in 25-foot borders.

The plants were flood irrigated after transplanting was completed and as needed during the first summer. No irrigation water or fertilizer were applied after the first summer. The mean annual precipitation at the TPMC is 11.5 inches. Weeds were controlled using mechanical and chemical methods.

Results and Discussion: Cold tolerance is the most limiting factor for eucalypts in the southwestern United States; most species cannot survive prolonged periods of below 30 °F (-2 °C). There were two good years to evaluate cold hardiness at Tucson. January, 1984 had twelve consecutive days with lows below 30 °F. February, 1984, had fourteen consecutive days with the low temperature at freezing or below. January and February, 1985, had six days below 30 °F; the lowest temperature was 24 °F on February 1, 1985. The annual rainfall ranged from 9.47 inches in 1979 to 24.5 inches in 1983. Many accessions have been rated with average or above average vigor ratings and good growth rate based on monthly visual observation and measurements.

There were several outstanding accessions in the 1979 IEP. Among the trees with a potential height greater than 50 feet, are E. camaldulensis T15053, E. pilligaensis T15110, E. thozettiana T15122 and E. woolsiana T15127. These four accessions exhibited excellent potential for windbreaks, shelterbelts and fuelwood production. Uniform growth habits, averaging greater than 40 feet in height, with dense foliage, was achieved by 1984. E. camaldulensis T15053 was used as the standard of comparison for vigor and growth rate.

Some of the medium tree accessions (15-45 feet), planted in 1979 exhibited good vigor; these include E. brockwayi T15047, E. gardneri T15080, E. sargentii T15118, E. populnea T15113, E. lessouefii T15096 and E. campespe T15056. They appear to have potential for windbreak use, as a result of having uniform, columnar growth habits and excellent foliage density. They are rapid growers, reaching 30 to 45 feet in height in five years.

Of the small trees (up to 16 feet in height) planted in 1979, only E. eremophila T15070, E. pileata T15109 and E. foecunda T15076 look outstanding. T15070 is a very attractive, willowy tree with a rapid growth rate, having achieved 90 percent of its potential height by 1984. T15109 is a more upright, columnar tree with abundant branches and dense foilage; it reached a height of 12 feet by 1984. T15076 is a dense, bushy tree with a height of 14 feet in 1984.

In the 1981 IEP, several species have had excellent vigor and growth. Of the tall tree accessions, only E. alba T09253 exhibited high vigor and attained a height of 40 feet by 1984. Of the small to medium trees, E. platypus T09294 had the highest vigor ratings and was described as having a very uniform, dense growth habit reaching a height of 15 feet by 1984.

Other Eucalyptus species may also be useful to the landscape trade in the southwest. The small trees include E. erythrocorys T15171, a uniform tree with dense foiliage and orange-red flowers; E. leucoxylon var. rosea, a small willowy tree with attractive red flowers; and E. kruseana T15090, a small, exotic-looking tree that would be a unique addition to any garden. Among the medium trees are E. occidentalis T15101, a very bushy tree, and E. sargentii T15118, a willow-like tree with dense foliage. E. phleba T15108 is a tall tree that may attain 50-60 feet in height; it has a spreading canopy with attractive foliage and bark--good qualities for a shelterbelt or shade tree.

Besides the main Eucalyptus planting trials at the TPMC, selected Eucalyptus accessions have been planted at Page Ranch, Arizona (in cooperation with the University of Arizona); several locations in Arizona (in cooperation with the Arizona Department of Transportation); Palm Springs and Antelope Valley, California; and Tule Springs Nursery, Las Vegas, Nevada (Nevada Department of Forestry).

INFLUENCE OF A NEEM (AZADIRACHTA INDICA) WINDBREAK PLANTATION ON MILLET YIELDS AND MICROCLIMATE IN NIGER, WEST AFRICA

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CARE International, Texas A & M Univ. and Institut National de Recherche Agronomique du Niger

The background information for CARE's windbreak project in the Majjia Valley of Niger can be found in the papers submitted by S. Dennison and N. Persaud (this conference). A multidisciplinary evaluation of this project was undertaken in March 1984. One objective was to determine the influence of the neem windbreaks on cereals production intercropped between rows and the mechanisms responsible for these effects. This paper summarizes the results of the 1985 growing season.

Field plot experiments were used to evaluate the response of millet to environment inside and outside the windbreaks, fertilizer application and distance from the windward row. Fertilizer treatments were : zero or 22.5 kg. P_2O_5 and 45 kg. N per hectare. Distances were 0.5, 2, 4, 6, 8 and 9.5 times the mean tree height (H) of the windward row. A local millet variety, GR-P1 (Guerguera), was planted at a density of 10,000 pockets per hectare. Ambient air temperature, windspeed at 5 heights above ground, and pan evaporation were monitored continuously inside and outside the windbreak rows throughout the growing season.

Table 1. shows that protection by the windbreak rows significantly increased dry matter production but showed no effect on grain yields or average grain weight per head. Fertilizer application increased grain yield and average head weight significantly but did not affect dry matter yields. Grain and dry matter yields were significantly reduced near the windbreak rows (Table 2). Fertilizers increased grain yields regardless of distance from the windward row (Figure 1).

Preliminary analysis indicates that windspeed may be most effectively reduced at the lowest sensor level and this reduction seems different for various stages of millet growth (Table 3). Maximum daily air temperatures were 1-2 degrees C. higher inside the windbreaks. Average reduction in pan evaporation due to the windbreaks was 1.5 mm./day.

Figure 1. Effect of distance from the windward row and fertilizer on grain and dry matter (DM) yields.

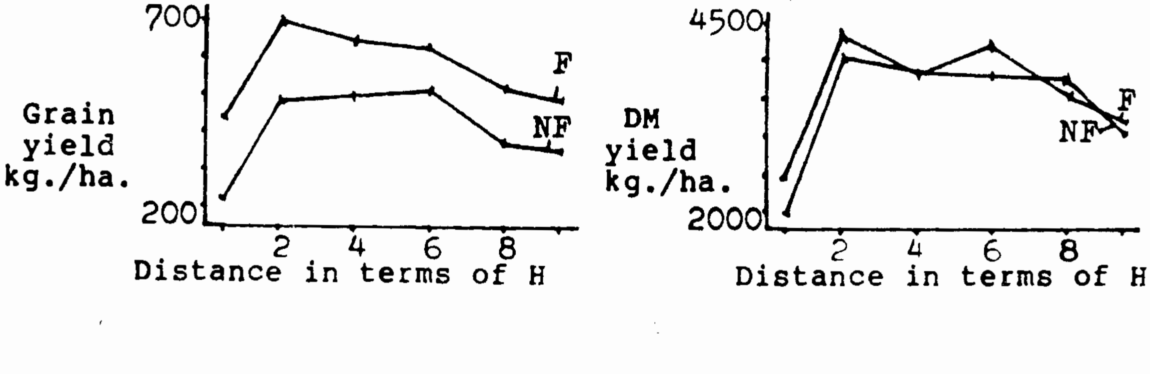

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Table 1. Effect of protection and fertilizers on millet grain yield, above-ground dry matter and average grain weight per head.

TREATMENT	Grain yield kg./ha.	Dry matter kg./ha.	Ave. wt./head gm.
Protected	488.0	3510.5	13.0
Non-protected	396.5	2092.5	11.6
	NS	*	NS
Fertilized	487.5	2861.5	13.4
Non-fertilized	397.0	2741.5	11.1
	**	NS	**

** : Means are significantly different at ≤1 % level
* : Means are significantly different at ≤5 % level
NS : Means are not significantly different

Table 2. Effect of distance from the windbreak row on millet grain yield, above-ground dry matter and average grain weight per head.

Distance from row (H=10.54m.)	Grain yield kg./ha.	Dry matter kg./ha.	Ave. wt./head gm.
0.5 H	327 a	2179 a	12.2 a
2.0 H	593 b	4211 b	14.5 a
4.0 H	572 b	3858 b	14.5 a
6.0 H	566 b	3971 b	13.7 a
8.0 H	447 ab	3661 bc	11.3 a
9.5 H	424 ab	3183 c	12.8 a

Means followed by different letters are significantly different at the 5 % level using Duncan's new multiple range test

Table 3. Averaged ratios of half-hourly mean windspeed at different heights measured simultaneously inside and outside neem rows for four periods during the growth of the millet crop.

	Days after emergence							
Sensor height above ground	28-31		40-43		55-57		65-66	
--cm.--	SW	W	SW	W	SW	W	SW	W
108	0.57	0.51	0.48	0.44	0.62	0.45	0.62	0.60
317	0.58	0.52	0.49	0.47	0.61	0.46	0.48	0.57
572	0.65	0.58	0.56	0.50	0.64	0.51	0.52	0.56
811	0.71	0.65	0.64	0.57	0.69	0.59	0.62	0.61
1151	0.82	0.74	0.68	0.60	0.79	0.68	0.73	0.70
No. values	47	11	48	21	26	24	30	27

Wind direction interval is ± 22.5 degrees

WIND-RUB DAMAGE TO KIWIFRUIT: AN INTERPRETATION OF CONTRASTING WINDBREAK AND TRELLIS EFFECTIVENESS

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In spite of widespread use of windbreaks by the kiwifruit industry, rejection of otherwise exportable fruit because of wind-damage and the breakage of new canes, results in significant economic losses each year. The 1982-83 season provided a valuable opportunity to examine and compare shelter effectiveness owing to unusually high and consistant winds throughout the period of kiwifruit development. Within a traditionally sheltered and trellised orchard, damage to vines increased rapidly with increasing distance downwind from close-spaced artificial shelter. Badly damaged vines had up to 58% of their export sized fruit rejected due to wind-induced frictional blemishes; the average loss being 15%. In striking contrast with this conventually managed orchard, vines trained on a nearby Tatura trellis with minimal use of windbreaks lost only 1% of the total crop due to wind-rub damage.

Wind-rub damage is caused by turbulent velocity fluctuations and analysis of the oscillatory motion of individual fruit show them to represent an underdamped system with a damping coefficient near 0.03 and a resonant frequency close to 2 Hz. Calculations of the reduction in turbulent energy at inertial sub-range frequencies using Kolmogorov's formula and velocity profile data from the literature suggest that natural shelter of the type often used in New Zealand should be very effective. This is contrary to our field evidence and we are led to the view that the advection of turbulence in the wake flow generated by the windbreaks themselves is responsible for the observed patterns of damage in the traditionally sheltered orchard. The low damage sustained by vines trained on the Tatura trellis in conjunction with minimal shelter, is attributed to the development of 'skimming flow' phenomena and the mutual sheltering of adjacent close spaced rows of foliage.

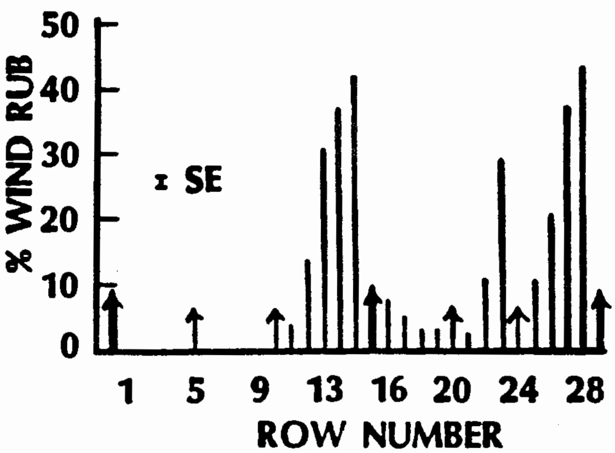

Fig. 1. The percentage of fruit of exportable size rejected because of wind-rub blemishes. Rows 1-9 not measured. Heavy arrows indicate natural shelter (8.5 m high) and small arrows show artificial windbreaks (5.5 m). Predominant wind direction is from left to right (from McAneney et al., 1984).

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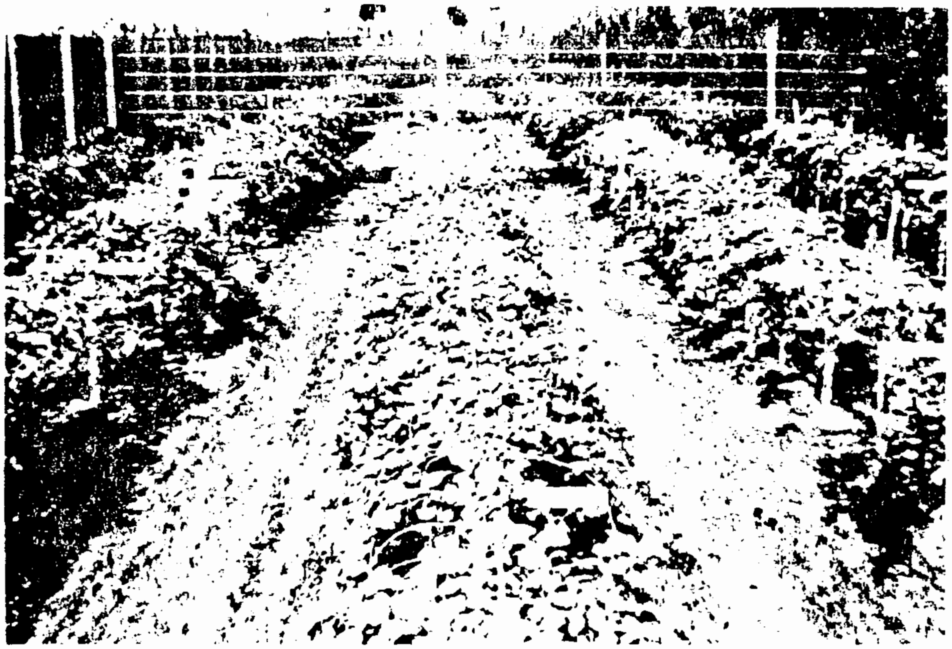

Fig. 2. Part of the surveyed orchard (site 1) showing positions of the artificial shelter relative to natural shelter and vines. Direction of prevailing wind is from right to left and the height of the T-bar trellis system is 2 m.

Fig. 3. Kiwifruit at site 2 growing on a Tatura-trellis system. The poles extend to a height of 3.2 m. The angle between the two arms of foliage is between 60 and 70 degrees.

PLANTING AND ESTABLISHMENT OF WINDBREAKS IN ARID ZONES

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Under Indian arid zone climatic conditions, where individual farmers have small holdings, there is need for establishing windbreaks of 2 or 3 rows of trees along field boundaries and to protect farm holdings from the onslaught of wind hazards. High wind velocities are predominant in these parts and are associated with sand storms with shifting of sand particles due to the loose texture of the soil. These are also complimented with an erratic, scanty and unpredictable rainfall pattern, with extreme temperatures in both summer (46° to 48 °C) and winter seasons (0° to 8 °C). Also there is a lack of vegetative cover on the soil surface. The small amount of vegetation is usually brushwoods or grasses. These are either over grazed or over exploited by livestock and human beings.

Windbreaks are narrow strips of trees and shrubs planted around farms, gardens, orchards, livestock sheds, farm houses, wells, etc. to provide protection against hot and cold wind currents as well as from the hazards of the blowing winds and moving sand particles. Width of windbreaks depend on the availability of land. Whereas shelterbelts are wide and long belts of several rows of trees and shrubs planted across the prevailing wind direction to deflect wind currents, to reduce wind velocity and to give general protection against sand movement on vast agricultural fields, canals, highways, railway lines, buildings or township, etc. Effective shelterbelts generally consist of 5 to 10 rows of trees and shrubs.

Windbreaks help to filter wind currents and thus reduce the wind velocity. Erection of wooden planks, stone slabs, etc., across the wind direction or along the farm boundary also help to reduce the wind velocity principally by remaining as wind barriers. They no doubt reduce wind velocity more abruptly than the tree rows and consequently cause considerable air turbulence which in turn cause greater wind damage to crops close to the barriers.

A certain amount of penetrability is essential in all types of windbreaks to facilitate slight movement of wind currents. This also serves to keep off the upper dry air from descending to lower protected levels and would thus increase the effective zone on the leeward side. Very dense and rather impenetrable windbreaks cause more damage on the windward side by recycling the wind currents and lifting up the sand particles close to the windbreak.

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Spacing of trees, length and width of windbreaks depends mostly on local climatic conditions, availability of land, and type of soil. Gaps, within the windbreak are more detrimental since such gaps would provide a tunneling effect which increases the wind velocity on the leeward side. No road or path should be permitted through the windbreak. Where essential, it should be made to cross the windbreak at an angle.

Seedlings are planted in pit planting at 2 metres apart within-the-rows and between-the-row at 2 metres. Staggered planting is advocated to check the wind velocity. While planting, 5 kg of farm yard manure plus a handful of insecticides may also be mixed per pit to give a boost to the plants as well as to protect the plants from insect damage. In the arid zones, all planting programmes are commenced with the onset of the monsoon season.

After planting, care should be taken to protect them from biotic interferences. Watering may be provided at regular intervals until the establishment of the plants for at least for a period of one year in arid zones, where rainfall is erratic, unpredictable, and scanty. Weeding and cultural operations are also necessary to check root and moisture competition. The following points may also be considered while selecting species for windbreaks.

a) The species should be hardy and fast-growing;
b) Should be wind firm;
c) Should form a dense canopy;
d) Should be long lived;
e) Should have deep root system, and;
f) Preference may be given to species which have tendency to develop erect or dropping branches to discourage bird perching.

In those cases where the lateral roots of the trees interfere with the field crops on the leeward side or inside the farm area, a deep trench 45 cm wide and 60 cm depth may be dug all along the tree belt at about 1 metre away to check the adverse effects from the lateral roots.

Benefits realized from windbreaks are enormous. They reduce the wind velocity and thereby reduce evapotranspiration and facilitate to conserve moisture; they add organic matter to the soil which promotes micro-biological activities in and around the land underneath and improve the soil structure and physical characteristics of the soil; they increase soil moisture; they check the force of the raindrops and allow the water to trickle down to the ground surface thereby reducing the splash, the puddling action of the soil and sealing of the pores spaces; they promote infiltration of water into soil which increase the underground water supplies; they have an ameliorating effect on the temperature and aridity extremes.

EFFECT OF STRUCTURAL VARIATION IN SHELTERBELTS ON WINDFLOW: A CASE STUDY OF A SUDAN SAVANNA ENVIRONMENT IN NIGERIA

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INTRODUCTION

The capacity of a shelterbelt to reduce wind depends on how effectively it can disturb the free flow of the wind. The magnitude of this disturbance is a function of the orientation of the belt relative to the direction of the wind as well as its permeability. Wind speed is reduced most if the belt is perpendicular to the direction of windflow. Permeability varies with the morphology of the species (a factor which determines the canopy density) and the spacing between the rows.

The area protected is a linear function of the height of the shelterbelt (H), while the intensity of shelter is inversely related to the porosity of the barrier (Jensen, 1983). The pattern of windflow downwind therefore depends to a large extent on the structure confered on the belt by the composite species since porosity is a function of structure. Barrier structures of low porosity cause speed to be more quickly restored than barriers with greater porosity, so shortening the shelter zone (Sturrock, 1975).

It has been suggested that a vertical structure which will permit sufficient through-flow of air at the ground level and has the density of the vegetation increasing with height in proportion to the logarithmic nature of the wind speed profile may give the best wind reduction and have the greatest downwind influence (Rosenberg, 1975).

This paper presents the results of wind flow measurements behind two different shelters in the sudan savanna zone of Nigeria.

MATERIAL AND METHODS

Two shelterbelts situated at Mele (Lat. 12° 48, Long. 09° 25) were selected for the study. One belt comprised of four rows of *Eucalyptus camaldulensis* flanked on both sides by one row of *Cassia siamea* while the other belt comprised of four rows of *Azadirachta indica* flanked on both sides by one row of *Cassia siamea*, all planted at a standard spacing of 3 m x 3 m. The belts were perpendicular to the prevailing dry season North-East trade winds and the wet season South-West winds.

The density of vegetation at the understorey of both belts was the same, since they had the same border crop, *Cassia siamea*. But the middle and upper stories were thicker in the *Azadirachta* belt, than in the *Eucalyptus* belt because the former has broader leaves, and branches more profusely. At the time of the experiment the shelterbelts were 3 years old and the mean tree height of the *Eucalyptus* belt was 6 metres while that of the *Azadirachta* belt was 5 metres.

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Wind speed was measured forthnightly at the 1.5 metre height at the leeward side of both belts at varying distances, and in the open area, simultaneously, during six dry season months. The distances selected were 1, 2, 5, 10, 15 and 20 times the mean tree height.

The pattern of windflow in both sheltered areas was obtained by plotting the relative wind speed (leeward wind velocity/open area wind velocity) against distance from the belt. The efficiency of each belt was estimated form the relation:

Efficiency = 1 - 100 (leeward wind velocity/open area wind velocity).

RESULTS AND DISCUSSION

Relative wind speed (Figure 1) at both sites was lowest at 2H and increased with increasing distance from the belt, as the wind speed tended to return to free air velocity. Wind reduction on the leeward side of the Eucalyptus belt extended up to 25H while it extended only up to 20H on the leeward side of the Azadirachta belt.

Wind reduction at 1H, 2H, 5H, 10H, 15H, and 20H distances were 64, 74, 70, 54, 25 and 10 percent respectively for the Eucalyptus belt, and 66, 74, 70, 49, 11 and 9 percent for the same distances respectively for the Azadirachta belt. The drop in wind reduction between 2H and the foot of the belt may be due to an eddy effect in this zone. Wind reduction at 1H by the Azadirachta belt was 2 percent higher than that by the Eucalyptus belt at the same distance. This suggests that there was more eddy and turbulence leeward of the Neem compared with that leeward of the Eucalyptus. The reason for this may be because the thicker vegetation density of Neem restricted more throughflow of air in the upper layers and caused more wind to be deflected from these layers above the crowns. As these winds descended to the leeward they caused more turbulence and eddying on that side compared with the corresponding side of the Eucalyptus belt.

The efficiency of each belt (Figure 2) was related to the wind reduction and decreased with increasing distance from the belt. At the 1H distance, the efficiency of the Azadirachta belt was 2 percent greater than that of the Eucalyptus belt. As explained for wind reduction the relative difference in the influence of the barriers at 1H may be due to the effect of eddies in that zone. The efficiency of both belts at 2H and 5H was at par, 74 and 70 percent respectively. However, beyond 5H the Eucalyptus belt was more efficient than the Azadirachta belt. The greater efficiency of the Eucalyptus belt beyond 5H may be due to its greater permeability in the middle and upper stories. Increased through-flow of air in these layers implies reduced deflection of wind over the crowns and therefore reduced turbulence downwind. These results suggest that under the conditions of this experiment the Eucalyptus/Cassia species combination was more permeable and reduced turbulence downwind than the Azadirachta/Cassia combination.

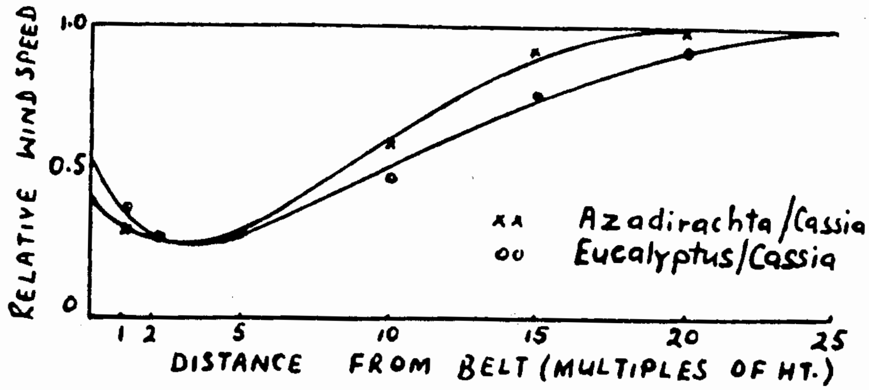

Figure 1. Relative wind speed as a function of distance from the belt.

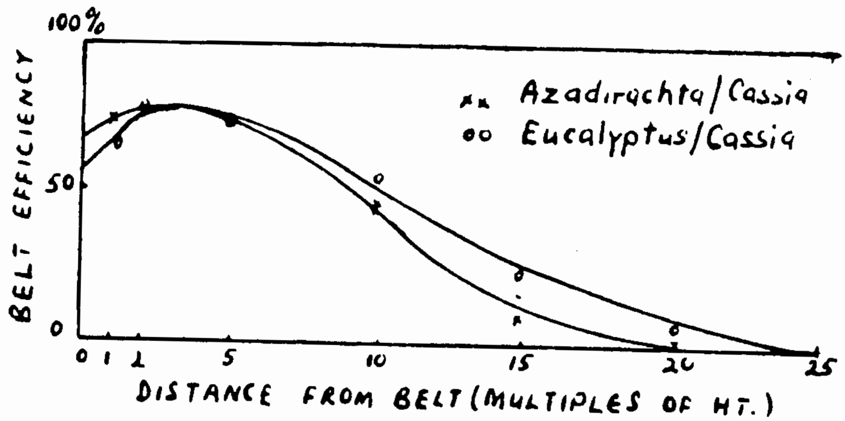

Figure 2. Shelterbelt efficiency as a function of distance from the belt.

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DILEMMA AND DIRECTION IN THE ROARING FORTIES: A TASMANIAN FARM SHELTER REVIEW

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Australia's island State stands 240 km off the southern coast of the continent between the latitudes 40° and 44°S, fully exposed to the westerly airstream, to chill incursions from the south and occasional hot northerlies from the mainland. Taking the form of a shield with main axes of 300 by 300 km, it is mountainous, particularly in the west, and much of the agricultural land is either elevated and open, or subject to strong winds directly off the sea. A winter biased rainfall in the farming areas ranging from an erratic 450 mm to about 1500 mm per annum, approximately superimposed on a trend from poorer to deeper, more fertile soils, is reflected in the tree cover. This varies naturally from open, grassy woodland to heavy, high forest, all dominated by arborescent eucalypts of different species according to site. It corresponds also with an agriculture as diverse as extensive pastoral management, opium poppies, fruit and freezer crops, and dairying.

Whereas all these enterprises would benefit from more attention to shelter, the greatest scope is in the sheep industry, where four million head are devoted mainly to wool production, including the finest of superfine. Such breeds are notoriously vulnerable to exposure, which is a prime factor contributing to an estimated annual loss of a half million lambs and to substantial mortality after shearing. Intensive livestock shelter within an extensive agricultural system, and under difficult conditions for tree establishment thus characterizes Tasmania's main shelter requirements.

Historically, English hawthorn (*Crataegus monogyna*), Lombardy poplar, *Pinus radiata*, *Cupressus macrocarpa* and other cypresses, all as single rows, have been planted for shelter. Traditionally there has been no management other than an occasional "topping", and fences have been set too close to the trees and ultimately neglected. This has resulted in a characteristic "draughty bottom" type of shelter, and many gross, moribund coniferous windbreaks, too costly to remove and replace. Despite such experience and the fact that land area has not generally been at a high premium, the minimum width/zero-management attitude induced in pioneers through generations of pushing back the bush remains very deep seated. This is all the more regrettable in view of recent trends involving indigenous vegetation.

Following land clearing, pasture improvement has entailed the introduction of exotic grasses and legumes, marked raising of nutrient levels and frequently a conscious elimination of all remaining vegetative shelter. Realization of the final phase is now occurring over vast tracts of Australia, and it has shocked the nation. This is the phenomenon known as rural tree decline, by which, in a system where regeneration of indigenous plants is impossible due to close grazing and enhanced pasture competition, the surviving trees prematurely lose their resilience and die. A whole

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plethora of natural and imposed factors is involved, but the process is one extending from infiltration by an alien culture, to isolation of trees and stands, loss of supporting vegetation, broadscale disruption of the environment and the simplification and breakdown of what have long been acknowledged as very fragile ecosystems. The significance of all this to farm shelter should not need to be stressed.

The values of trees on farms, other than for timber, are not afforded due recognition by State forestry and agriculture services. Into this near vacuum of neglect, through Federal and media sponsorship, has slipped the alternative tree movement. This ought to be of some concern to the professionals because of the propagation of misconceptions relating to shelterbelt aerodynamics and design, tree genetics, and native trees and shrubs vis a vis exotic species. Shelter principles elucidated decades ago in the northern hemisphere are being devalued by facile interpretations lacking the benefit of Australian research and relevance. "Local provenance" is the popular catch-cry, in the face of the fact that many environments have been changed beyond the capacity of the indigenes to thrive, and regardless also of the hazards of excessive selfing, inbreeding depression and narrowing genetic bases in collecting from remnant trees.

In this context it is appropriate to consider the place of native trees and shrubs in shelter practice. Contrary to their reputation earned overseas, eucalypts are rather poorly adapted to shelter planting in Tasmania, at least for intensive farming and very exposed situation. Their characteristically sparse foliage is commonly further thinned by insect attack and opened by architectural processes. Moreover the crowns rapidly distance themselves from the ground, leaving a void that is difficult to foliate. The delicate "bud-less" shoots do not withstand severe or salt exposure, and seedlings are susceptible to frost in the modified agricultural climate. Mature trees may not accommodate to the changed soil conditions and their sensitive root systems are vulnerable to cultivation and disease. Not all eucalypt species coppice or respond well to pruning; but they do make heavy demands on soil moisture and shed large quantities of woody and chemically inhibiting debris. The native shrubs and small trees required to complement these eucalypts tend to be lacking in variety in the harsher environments, and to have rather transitory life cycles which detract from their shelter value. In effect, single row and duplex structures involving eucalypts are generally unsatisfactory in Tasmania; and without close management the now popular three-row shelterbelts of natives might also prove wanting in the long term.

All this is in direct contrast to the extensive farming situation, where many advantages are now seen to lie with the indigenous plant systems. In-depth, natural shelterbelts are aerodynamically and aesthetically valid and also provide habitat and corridors for predators and parasites of pasture grubs and other pests. However, the high cost of nursery stock, vast scale, genetic considerations and practical problems of regenerating or recreating ecosystems all give point to the urgency of securing shelterbelts from the indigenous vegetation while the opportunity remains.

Farm shelter in Tasmania has characteristically been single-purpose, but its benefits have proved inadequate as incentives to proper management. Prompted by pioneering work in New Zealand, the recognition is dawning that direct material production and financial returns offer the best prospects for managed shelter. The first pine windbreaks engineered by pruning to maintain optimum permeability and produce quality timber are now being established. A second outside stimulus, from neighbouring Victoria, is for whole-farm or catchment planning, in which shelter is integrated with all the other uses and values of trees and forest associations on the land. In such concepts lie the direction of future efforts in Tasmanian farm and shelterbelt forestry.

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INFLUENCE OF WOOD-HARVESTING METHOD ON WIND PROTECTION BETWEEN ROWS OF A NEEM(AZADIRACHTA INDICA) PLANTATION IN NIGER, WEST AFRICA

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The neem tree introduced from India is now ubiquitous in the zone south of the 250-300 mm isohyet in Niger. In 1975 C.A.R.E. International with cooperation from local residents initiated a systematic planting of neem trees in the Maggia of South Central Niger. To date about 360km. of trees were planted in double rows 100m apart, oriented approximately North/South across the long axis of a valley. Trees were spaced 5mX5m within the double row.

After 10 years the villagers on whose land the trees were planted wished to begin harvesting wood from the trees. Since the trees provide protection from prevailing hot, dry winds and are believed to improve the yield of cereals alley-cropped between the rows, it was necessary to to determine the best method for harvesting wood that would provide maximum removal without impairing this protective function. The objective of this study was to investigate the influence of several possible wood-harvesting methods on wind protection between the double rows.

The methods of harvesting were as follows: (A). All trees in 100m of a double row pollarded, designated as "complete pollard". The pollarding consisted of removing all wood more than 2.5m above the ground, (B). All trees in 100m of the eastern row pollarded as (A), and designated as "one-row pollard", (C). One in every consecutive group of 4 trees in 100m of a double row pollarded as (A), such that cut trees were never adjacent and there were always 3 uncut trees between cut trees in either row, designated as "one-in-four pollard", and (D). Removal of the branches overhanging the alleys from both sides of the double crown formed by the trees for 100m designated as "partial pollard".

The effects of these treatments were compared to an uncut control. All cuts were made between June 2 and June 5 of 1985. Average height of trees measured on a sample of 80 trees was 10.7 ± 1.6m. Instrumentation consisted of 5 anemometers mounted on a tower at 108, 317, 572, 811, and 1151 cm. above the ground. One such tower was set up outside the trees and another positioned at 5 times the height on the eastern side of the treated row as appropriate for each treatment. On the outside tower a wind direction sensor was mounted on the same arm as the second anemometer. Observations of windspeed were made simultaneously inside and outside the plantation at intervals of 60 sec. with automated data-logging equipment. Averages of these observed values were output at half-hourly intervals. For each treatment a sample 169 such values were obtained. These values were grouped into 8 categories using the measured outside half-hourly mean wind direction in intervals of 45 degrees. Ratios of inside to outside mean windspeeds were calculated for each pair values in each group and these ratios were averaged.

Dates of sampling were : uncut control- July 8-11, A- June 24-27, B- June 9-11, C- June 19-22, and D- June 15-18. Data were analysed

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assuming samples were from a stationary time series and results are presented in table 1. Wind was mainly from SW, W, and NW during the sampling period. In general average ratios were less than unity. At each height sampled the effect of harvesting method on windspeed reduction depended on the wind direction. As expected, the complete pollard considerably lowered the protection from wind for all directions, especially for wind from the SW. Reduction with partial pollarding for most combinations of height and direction was as good as the uncut control. Except for winds from the NW the one-row and 1-in-4 pollard reduced wind protection significantly compared with the uncut control. Partial pollarding may not yield as much total wood as the other methods but reduction in prevailing windspeeds greater than 30% can be maintained between the rows.

Table 1. Influence of wood-harvesting method on averaged ratios of inside to outside half-hourly mean windspeeds sampled at different heights above the ground for main prevailing mean wind directions.

Wood-harvesting method	Height above ground cm. 108	317	572	811	1152	No. values in sample
	A. Mean wind direction interval= SW ± 22.5 degrees					
Uncut control	0.58a	0.59a	0.68a	0.74a	0.83a	89
Complete pollard	0.92b	0.85b	0.94b	0.93b	0.95b	49
One-row pollard	0.73c	0.72c	0.79c	0.82c	0.87a	75
1-in-4 pollard	0.85d	0.81d	0.87d	0.92d	0.98bc	56
Partial pollard	0.66e	0.56a	0.59e	0.64e	0.76d	45
	**	**	**	**	**	
	B. Mean wind direction interval= W ± 22.5 degrees					
Uncut control	0.41a	0.44a	0.51a	0.59a	0.67a	46
Complete pollard	0.81b	0.73b	0.80b	0.81b	0.81b	30
One-row pollard	0.64c	0.63c	0.77c	0.70c	0.74c	60
1-in-4 pollard	0.66cd	0.63cd	0.67d	0.70cd	0.77cd	63
Partial pollard	0.58e	0.50a	0.50a	0.54a	0.64a	45
	**	**	**	**	**	
	C. Mean wind direction interval= NW ± 22.5 degrees					
Uncut control	0.55a	0.54a	0.63a	0.73a	0.79a	14
Complete pollard	0.82b	0.72b	0.88b	0.76a	0.76a	16
One-row pollard	0.65a	0.63a	0.65a	0.67a	0.70a	14
1-in-4 pollard	0.65a	0.61a	0.66a	0.68a	0.72a	24
Partial pollard	0.47a	0.44c	0.48c	0.52b	0.59b	14
	**	**	**	**	**	

** F-statistic significant at 1% level
Means not followed by same letter are significantly different at 5% level.

THE USE OF ARTIFICIAL WINDBREAKS FOR PROTECTING KIWIFRUIT IN NEW ZEALAND

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In recent years New Zealand has significantly increased its production of kiwifruit. In the period 1980-84 exports increased from 16,000 tonnes (NZ$34.5m) to almost 45,000 tonnes (NZ$126m). This trebling of production has been matched by a corresponding increase in the land used for kiwifruit, increasing from 5372 hectares in 1980 to 16,013 hectares in 1984. Although the general climate is suitable for kiwifruit, they tend to suffer from wind damage in a number of ways which include:

1) Breakage of the young canes which would carry the next year's fruit.
2) Leaf damage or premature defoliation causing reductions in photosythesis.
3) Damage to flowers.
4) Suppression of bee activity and hence poor pollination.
5) Wind rub resulting in the rejection of fruit for export.
6) General growth retardation - especially noticeable in young plants.

Hence, in almost every case, the development of new land for kiwifruit has necessitated the establishment of windbreaks.

Traditionally wind protection has been provided by planting natural shelterbelts around the perimeter of each block (typically 100m long and 40m wide). However experience has shown that the use of natural shelter does have a number of disadvantages:

1) The establishment of natural shelter can take 2 years or more before adequate shelter is achieved.
2) Shelterbelts can occupy as much as 30% of the orchard area.
3) Shade can significantly effect fruit production. Some measurements have shown that kiwifruit rows adjacent to natural shelter were producing only 13 flowers/cane as opposed to 32 flowers/cane for rows adjacent to artificial shelter.
4) Shelterbelts are made up from living trees and these demand both water and nutrients. This tends to lead to root competition between the vines and the shelter. The combined effects of shade and root competition have led to depressed production which in one case was measured and shown to be: 5 trays/vine on a row adjacent to natural shelter as opposed to 25 trays/vine on a row adjacent to artificial shelter.
5) Shelterbelts can easily become too dense and hence lead to poor wind protection and high turbulence generation.
6) Shelterbelts can harbour pests and diseases.

Despite this list of disadvantages natural shelter is still extensively used since it does have the advantages of being relatively cheap and long lasting. In addition good management can minimise the significance of many of these problems and so it seems likely that natural shelter will remain the best choice for boundary shelter and other situations where shade not so damaging.

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In the early 1970's artificial shelter was promoted in New Zealand as a means of providing better total wind protection whilst attaining maximum land utilisation. Since that time an estimated 3000km of artificial shelter has been installed. This construction has required significant investment, for example typical 1985 costs were around NZ$35,000/km for artificial windbreaks as opposed to NZ$2,000 for natural. Although artificial shelter has been used to protect a variety of crops it is only with kiwifruit, where there is sufficient income per hectare, that its use is widespread.

In their most common form these horticultural windbreaks are constructed from a porous(typically 30-50%) plastic woven or knitted cloth supported and constrained by wires which are themselves supported by vertical cantilever wooden poles. Typical fence heights are between 4.5m and 7m. Variations on this theme include Paraweb, which is a lattice constructed from 50mm wide plastic strips, wooden lattices, guyed poles etc.

The ways in which these artificial windbreaks have been used also varies considerably. Since some of the cloths used only have a field life of 5-7 years the artificial shelter is often used as instant temporary shelter. This has too major advantages, in the first place it means that the vines can be planted in the first year and hence fruit production is much quicker and secondly it means that the permanent natural shelter has a chance to grow in a sheltered enviroment in its early years.

In other situations longer lasting permanent artificial shelter is used. This not only has the advantage of early fruit production but it also minimises the amount of land required for the windbreak system. On some developments the complete windreak system is articial and it is intended that it should remain so.

Artificial shelter is also extensively used to try to overcome problems in existing natural shelterbelt systems. This may mean blocking gaps in the natural shelter but more often it is used to provide additional shelter where the existing system is inadequate. One very common technique is to construct overruns. These are fences constructed above the vines with the lower edge of the cloth at about 2.5m off the ground. By using this technique extra shelter is provided without taking up any extra valuable land.

Overruns are also increasingly replacing internal natural shelterbelts. By doing this an extra row of kiwifruit can be planted in place of the natural shelter and the overrun constructed above it. This substitution can also lead to increased production from ajacent rows due to reduced shade and root competition.

In the past 15 years artificial windbreaks have been a growing industry in New Zealand but it now seems unlikely that this trend will continue. In recent years the returns for growing kiwifruit have decreased and so the justication for expenditure on artificial shelter has become marginal. What may happen in the future is uncertain but it still seems likely that artificial shelter will remain a part of New Zealand's Horticulture.

ENCOURAGING SHELTERBELT PLANTING IN AUSTRALIA

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Abstract

Australia is an ancient and fragile land which, in the 200 years since European settlement, has seen dramatic changes to its vegetation, fauna and soils through the direct and indirect influence of man. Many of these changes have been destructive, with far-reaching effects on the ability of the land to sustain its productivity.

The removal of a major portion of the country's native tree cover, and its replacement with crops and pastures has, in many areas resulted in major land degradation problems of soil erosion and salinity. In much of the countryside, the scattering of residual shelter trees, which were often retained in farmland when the land was first cleared, are now steadily deteriorating and dying, without regeneration. This rate of loss has been calculated at a level of approximately 1% per year in the last 20-25 years in a number of areas.

There is plenty of evidence from published research work concerning the value of farm shelter, and many farmers have recognized that they have much to gain from well-established shelter. However, it is evident that, in general, far too little attention has been paid by farmers and landowners to maintain existing farm tree cover or to establishing new farm shelterbelts or other tree cover. Where tree planting has been undertaken by landowners, either as replacement for lost native tree cover or as new farm shelter, it has mostly been in the form of shelterbelts. These are frequently insufficient for total farm protection, inadequate as replacement for lost trees and substantially alter the nature of the rural landscape.

This landscape alteration arises from the changes in the total tree numbers, changes in distribution from a parkland style to a series of straight-line plantings, and changes in species from local species to other Australian or exotic species.

Tree decline in rural areas, with the associated problems of soil erosion and salinity, is seen in Australia as one of the major conservation issues facing the country at the current time.

To counteract this rural tree decline, Governments, Industry and Community Groups, throughout Australia are in the process of developing programs promoting the restoration of trees to farmland as part of complete farm planning. These programs combine public promotion of the needs for rural tree planting, technical advice, and financial incentives, together with funding of community group projects. The detail of programs

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vary between states, and include encouraging the retention and management of native vegetation, promoting greater use of natural regeneration and direct seeding practices, promoting wider use of local native species, and development of the multiple-use aspects of shelter plantings.

Examples of current programs include, at a national level, the National Tree Program and the Greening Australia Program, and at a state level, the Tasmanian "Project Treescape," the South Australian "Native Vegetation Retention Scheme," the Victorian "Rural Trees Incentives Program," and the New South Wales "Trees on the Farm" Program. Other programs are conducted by municipal authorities, industry groups and a multitude of concerned community groups.

At this time, there appears to be a wider understanding of the need for tree planting on farmlands, and the incentives offered have resulted in significant increases in plantings. It is also evident that the greatest incentive to farm tree planting has been the presence or serious risk of occurence of major land degradation problems. In localities where soil erosion or salinity are causing serious soil damage, tree planting activities have increased significantly in recent years as part of total farm programs to counteract the loss of productive soil - one of the nation's major assets.

WINDBREAK POLICIES IN PAKISTAN

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ABSTRACT

Before going into the policies of Pakistan for establishment of windbreaks, the history of development of an overall forest policy in the country would have to be gone over. This would provide an over view of the forestry situation in the country and as to how far forest policies have been effective enough to meet the desired objectives.

1. History

Forest policy for pre-partition India was enunciated in circular No. 22-F, October 19, 1894. Its salient features were: the constitution of reserved and protected forests; preservation of physical and climatic conditions; supply of timber; supply of minor forests products; preservation of forests in catchment areas because of their protective role; identification of rights of the people living in the forest areas, etc.

A very significant feature of this policy was that the forests burdened with rights and privileges should be maintained for the entire satisfaction of the local needs which should take precedence over construction of income and that only those restrictions may be imposed as may be necessary for the preservation of the forests. This provision due to multiplication of the rights of the people and the increase in population has very adversely affected the perpetuation of a meagre forest resource in Pakistan. It was also provided in the policy that pastures and grazing grounds which are usually forests in name should not be subjected to any strict system of conservation. This, when put into practice, has very seriously affected the productive capacity due to incessant pressure of grazing. This concession is not allowing the vegetation to recover. The most palatable and nutritious plants are devoured first. As a result of that, only noxious weeds are thriving.

Since the 1894 policy was meant for conservation of the forests which formed 22% of the total land area, it could not be effectively applicable in a country which did not boast of more than 2.5% area in production forests.

In Pakistan, the first ever step towards formulating a forest policy was the Resolution of October 12, 1955. It envisaged:

- Forestry should be given a high priority in national development plans.
- Sound management should be extended to private forests.
- Necessary powers should be obtained to control land-use under a coordinated programme of soil conservation and land utilization in areas subject to or threatened with soil erosion.
- Public support should be enlisted for the execution of forest policy.
- Forests should be classified on the basis of their utility and objects.
- The beneficial aspects of forestry should get precedence over the commercial.

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- Forest area should be increased by such measures as follows:
  i. Reserving 10% of canal irrigated land and 10% of water for raising irrigated plantations.
  ii. Growing trees along canal banks, roadsides, railway tracts and on arable waste land.
  iii. Encouraging farm forestry on cooperative basis by village communities in compact blocks of crop land set apart for the purpose.
- Timber harvesting should be improved.
- All forests should be managed under working plans.
- A properly constituted forest service of fully trained persons should be made responsible for the implementation of forest policy.
- Forest research and education should be organized on proper lines.
- Adequate protection of wildlife and of their habitat should be provided.

It was followed by another directive on forest policy watershed management, range management and soil conservation by the Government of Pakistan Ministry of Agriculture and Works, Food and Agriculture Division letter No. F. 4-30/62-P-4 dated 20.6.1962. In this policy directive, forestry and allied disciplines were categorized separately for the first time into forestry; watershed managment; farm forestry; range management; soil conservation, etc.

In the forestry sector it was emphasized that the management of each forest should be intensified to make it a commercial concern; utilization methodology should be improved; rights in the forests should be progressively acquired and afforestation should be taken up along roads, canal, railways tracts and river banks.

In the watershed management areas the conservation of the entire watershed was considered imperative and implementation of several programmes of soil and water conservation was suggested.

For soil conservation it was suggested that programmes should be started for the conservation of soil in the mountainous areas by making provision of machinery and undertaking such works as land terracing, construction of small dams and check dams and establishment of adequate research and extension services.

As regarding range management, it was provided that improvement of range lands was highly important and measures should be taken for protection and increased production from the over-grazed lands.

The farm forestry programmes were highlighted under this policy directive and it was provided that in order to encourage farm forestry, research should be undertaken on quick growing commercial tree crops for each ecological zone; research should also be undertaken on shelterbelts and windbreaks and pilot projects started on agriculture farm. It was further suggested that pilot projects should also be started for the cultivation of trees on saline and waterlogged lands.

It would be seen from the above that provision of growing trees along canal banks, roads, railway tracks and on arable waste lands was provided as far back as 1955. This programme was further strengthened through the 1962 directive on forest policy wherein it was clearly indicated that research in shelterbelts establishment should be started immediately.

In the year 1980, while formulating National Agricultural Policy, forestry and wildlife were given due importance and several measures were suggested to improve the forest cover in the country. A well-planned integrated and coordinated forestry planning and development program on provincial and national levels was suggested along with a bigger thrust on tree planting with fast growing tree species in areas outside the forests. It was also provided that farmers and the general public should be motivated and encouraged to plant trees on the farm land and other suitable locations. It was, however, indicated that tree planting should not obstruct flight by plant protection air crafts and that the forest department should continue to provide seedlings and technical assistance.

2. The necessity of windbreaks and shelterbelts in Pakistan.

If windbreaks and shelterbelts are needed in any area of the world, Pakistan enjoys the highest priority. The mercury often goes as high as 45 °C. Storms loaded with hot and scorching sand moving at the speed of 100 km per hour April through September bring misery and poverty to the unfortunate inhabitants of arid lands. Hot and desiccating winds accelerating the evapotranspirational processes cause wide-spread damage to tender agricultural crops and fruit orchards.

In the south and south-western parts of the country, sand storms rob the soil of its productivity by blowing away fine clay and silt particles and the lighter organic matter, leaving behind coarse, unfertile sand very often collected in the form of big sand dunes. At present, 40% of the land area is under this kind of erosion activity in the Kohistan Kalat, Thal and Registan Deserts. In extreme cases the affected areas are covered with huge sand dunes which keep on shifting from place to place with high velocity winds, thus damaging habitations, agricultural fields, and natural plant growth. The ponds and irrigation channels fill with sand and the roads and rails get blocked taking hours to re-open. Thousands of dollars have to be spent every year to keep the irrigation systems, roads, and railway tracks running. The whole coast line is confronted with the problem of sand movement, the sea breeze depositing the sand on many habitations forcing the people to abandon their abodes for safety and better living. The habitations of Pakistan, particularly those of Pasni along Baluchistan coast, are a vivid example. It is apprehended that in case the process of sand shifting continues, the town of Pasni would disappear under about 6 m of sand. The people living in the deserts are aware of the usefulness of windbreaks and shelterbelts and in certain areas planting is done as a rule. However, since land holdings are small, it is almost impossible for the small farmers to earmark land for shelterbelts or windbreaks.

3. The draft forest policy.

In the year of 1984, a forest policy draft was prepared by the author of this report. In that draft high emphasis has been placed on biomass production by not only trying to increase the production per unit area from the existing forests but also planting of trees on all marginal and waste lands has been suggested. The importance of a social forestry programme to motivate the farmer to plant trees on his land in blocks, rows, or in scattered form, has been highlighted together with some recommendations to provide incentives such as giving a rebate on water rate, land taxation, credits from banks, and making of arrangements for marketing of the produce. To achieve the desired goals, a concerted effort has been suggested jointly by the forest department, rural development department and the local government. Also adoption of a multipurpose tree production system in households, farms, and forest estates has been recommended for production of fuel, fodder, timber, fibre and several other minor forest products obtainable from such multipurpose trees. From the available data it has been calculated that against the present annual consumption of 19 M m^3 of fuelwood, the country would need about 42M m^3 by the year 2000. Similarly, against the present consumption of about 2M m^3 of timber, 3.46M m^3 would be needed by the turn of the century. It has also been established that 90% of the total fuelwood requirements and 58% of timber needs are being met from the trees grown by the farmer on his cultivated and marginal land. On the contrary, in view of the current shortage in food supplies, it is obviously not possible to release more cultivable land to the forest departments for raising plantations. The country would, therefore, have to depend on supplies of wood from private land for quite some time in the future. Thus a systematic planting of trees on such lands would have to become the cornerstone of all future forest policies in Pakistan.

It has to be kept in mind that in developing countries like Pakistan, wood still remains the principle source of heating and cooking. Dependence on limited supplies of wood has led to a virtual wood crisis. 87% requirements of domestic energy are being met from non commercial fuels out of which about 50% comes from wood. However, a scientific approach is needed now, and the farmer has to be guided as to whether he should go in for shelterbelts, windbreaks, or wood lots; what should be the orientation of his tree rows; which species would compete less with his agricultural crops for water, nutrients, light; which are the most suitable, fast-growing species for early returns, etc. Once the farmer starts getting reasonable returns from the tree belts on his land and realizes the beneficial effect on his crops, there would be no stopping him. In addition, the country should keep on producing the desired quantity of wood on a sustained basis from this erstwhile source.

Role of Wind-breaks and Shelter-belts on Wind Erosion, Moisture Conservation and Crop Growth - An Indian Experience

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Large areas in North Indian plains and Penisular India are affected by severe wind erosion. Wind-breaks and shelter-belts played a vital role in controlling the erosion, stabilizing agriculture and meeting fuel and fodder needs of its population. This communication reports the extent and characteristics of the arid region, its wind erosion problems, and summarises the Indian experience on effects of shelter-belts and wind-breaks on wind erosion, conservation of soil moisture and crop yields.

Extent and characteristics of arid region : Indian arid zone spreads over 32 million hectares including 23.5 million hectares of sand dunes. Major part (28.6 million ha) of this is situated in the states of Rajasthan, Gujarat, Haryana and Punjab. Rest of the area is located in the lee of the Western Ghats in Maharashtra, Mysore and Andhra Pradesh. These arid zones are characterised by low rainfall, low humidity, hot summers, large annual and diurnal variations in temperatures, and high wind velocities averaging 15 to 25 km/hr, occasionally reaching 50 to 60 km/hr. It has high population density and has a long history of exploitation of its natural resources.

Wind erosion is a serious problem in the region. In north India the Indus to the Mahanadi and Gulf of Cambay to the Shivaliks, the lower atmosphere remains laiden with dust particles during summer months. In this area, one can see considerable amount of eroded soil lying against canal, railway and road embankments, field bunds, buildings, trees, plants and stubbles in fields. Wind deposits of Thar desert origin have been recorded as far as 400 km away in outer Himalayas. Soil removals of 1400 t/ha during April to June from a bare flat land are not uncommon.

Wind erosion control : In arresting wind erosion on coastal areas of India, plantation of <u>Casuarina equisetifolia</u> has been successfully used. At Jodhpur, shelter-belts consisting of <u>Prospis juliflora</u>, <u>Cassia siamea</u> and <u>Accacia tortolis</u> as the side rows with <u>Eucalyptus terminals</u>, <u>Azadiracta indica</u> and <u>Albizia lebbak</u> as central rows, decreased wind velocity by 36 and 46% during summer and monsoon seasons, respectively at a distance two times the height of shelter-belt. Soil removal in 20 days period during April was 3 t/ha from sheltered against 72 t/ha from the unsheltered area. The micro wind-breaks of brush wood along with grasses/creepers helped stabilizing sand dunes. Annual wind strips of pearl millet, maize, castor (<u>Ricinus communis</u>) and sewan grass (<u>Lasiurus sindicus</u>) were very effective in checking the movement of sand.

Moisture conservation : Wind-breaks and shelter-belts reduce evaporation loss by providing shade and decreasing wind speed and turbulance. A loamy sand had higher water content in sheltered than unsheltered area during April and June (Fig. 1). The difference in soil water content of sheltered and unsheltered area was greater in 15-30 cm than 0-15 cm layer.

Crop yields : The practice of raising micro shelter-belts consisting of growing strips of wind erosion-resistant crops across the prevailing wind and alternating with the crop to be protected have proved very useful. At CAZRI, moong (<u>Phaseolus aureus</u>) and moth (<u>Phaseolus aconitifolius</u>) grown under the protection of sewan grass and castor out-yielded control by

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11.3 and 9.7 per cent, respectively. In addition, 1,650 kg/ha of dry grass and 746.5 kg/ha of castor seed was obtained from the shelter-belts. In an other experiment, three rows of tall growing pearl millet planted across the prevailing wind direction increased water use efficiency and production of summer grown okra and cowpeas (Table 1). The micro shelter-belts of annual barriers are known to fail in situations of prolonged drought and on low water retentive soils. Under these situations, perennial shelter-belts would be more helpful. Studies indicated better growth and yield of crops and natural vegetation under the canopy of trees in unirrigated conditions. But under irrigated conditions, wind breaks had adverse effect on yield of field crops. The trees planted in north-south direction caused

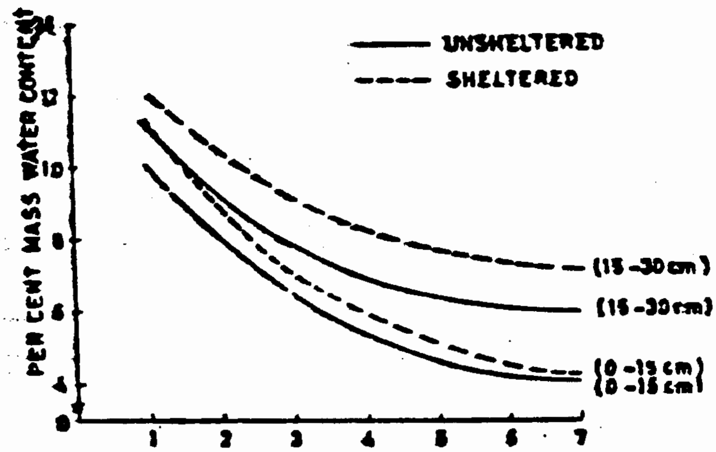

FIG.1. SOIL MOISTURE CONTENT IN AREAS UNSHELTERED AND SHELTERED BY SHELTER BELTS

Table 1. Effect of micro shelter-belt on vegetable yield

Crop	Unsheltered	Sheltered
	----- q/ha (average of six years) -------	
Okra	23.5	33.3
Cowpeas	28.6	34.6

less deduction in yield than planted in E-W. There was a less decrease in yield than planted sown on eastern aspects. The distance upto which the trees affected the crop yield depended on tree grown, cropping season and type of crop. Reductions of 16 to 64% in different crops were recorded at 1 m distance from tree line, it diminished to almost nil at distances 2 to 3 times the tree height. Reduction in crop yield followed the order : potato – paddy – wheat. The reduction in crop yield was attributed to shade, moisture and nutrient competition of tree roots with main crop.

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SHELTERBELT ESTABLISHMENT IN NORTHERN NIGERIA

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In 1978, the Nigerian government established a National Committee for Arid Zone Afforestation (NCAZA). The aim was to afforest the arid zone to prevent the spread of desert and by ameliorating the climate increase crop and livestock production. The Federal Government provided resources for the production and distribution of tree seedlings, together with fencing materials, to individuals and organizations in the arid zones.

Shelterbelts have been planted in northern Nigeria since the early 1960's, with more strenuous efforts after the Sahelain drought of 1973-74. The system used is linear belts, though in some cases block planting was used, ambiguously called circular shelterbelts. Experimental work in northern Nigeria and neighbouring Niger has shown that yields of most local crops can be increased by shelterbelts.

The NCAZA programme implimented and augmented by the state forest services has been very successful in producing seedling trees. The main species used were both exotics, Eucalyptus camaldulensis and Azadirachta indica, grown in polythene tubes for four to five months in the nursery to produce transplants 30 to 50 cm tall. The low rainfall 380 to 760 mm, falling between June and September with an unreliable start, leads to problems in scheduling site preparation and planting. In extreme cases the wet season is as short as 80 days. The following dry season has temperatures over 40°C with strong dry Harmattan winds blowing from the Sahara desert to the north. These climatic conditions together with low site fertility makes establishment of the shelterbelts difficult.

The system used generally involves site clearance by hand, pit planting of the seedlings and either mechanical or manual weeding of the trees for two years. Establishment has frequently been very poor because of lack of resources or untimliness of operations. Losses have also occurred from the activities of Fulani graziers and when farmers have grown crops between the trees. This lack of success in establishment has seriously reduced the programme to establish shelterbelts in the arid zone. Consideration is now being paid to the management of the older shelterbelts to provide fuel, poles and fodder as well as shelter.

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Local Benefits of Windbreak Plantings in the West African Sahel

by

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Villagers in the Majjia Valley in south central Niger farm at a subsistence level. All too often in the recent past they have had to rely on the world community of farmers to live from one year to the next. Rain, less than 16 inches of it in an average year, is the most critical factor in this valley that is blessed with rich soils, by Sahelien standards.

Farmers, realizing that the strong, persistent winds of the dry season were blowing their valuable farm land away, approached the local forester to see if there wasn't something he could do. The forester and a U.S. Peace Corps Volunteer latched onto the idea of windbreaks, and with backing from CARE (the international relief and development agency) planted 16 kilometers of double row windbreaks of neem (*Azadirachta indica*) in 1975.

In the 11 years since more than 300 km of windbreak have been planted. These will eventually protect over 3000 ha of farmland -- from dry season winds, from crop-damaging winds during the monsoon season, and will yield valuable wood for construction and fuel in a region woefully short on both.

Inhabitants of the Majjia Valley are, today, very cognizant of the benefits accruing to them due to the windbreak plantings. In a recent sociological evaluation, eighty percent noticed an increase in crop production when their fields were inside the protection zone. Only 16 percent thought there were some disadvantages, and most of these were due to the undeniable fact that the cultivable area is reduced (due to shading) as the trees mature.

But despite this reduction in area, a recent examination of crop production in the windbreak zone found that the land there is actually more productive. On a per unit area comparison, windbreak protected fields produced, on the average about 17 percent more than grain cultivated outside the windbreaks.

Unfortunately, most of this benefit is not in the farmer's pocket until the windbreaks are harvested. When the trees are cut for the first time, as they were in 1985, these benefits translated into about $15.00 per hectare for the farmer with windbreak protected land. In subsequent years, due to regrowth of the trees -- and more shade again -- this benefit is expected to be reduced to about $12.00/ha/yr.

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Perhaps even more important to the Majjia Valley as whole is the increase in wood supply in the region due to the maturing windbreaks. Prior to any cutting of these trees, Valley women, in 8 out of ten cases, reported that fuelwood was harder to find today than it was ten years ago. Most wood for cooking comes from plateaus surrounding the Valley -- a day's trek for most.

Cutting of the windbreaks has, at present, been restricted to an experimental basis. Local farmers, local government officials, and the forest service have all expressed a strong desire to develop an equitable management scheme for the windbreaks. CARE, in its recently completed two-year evaluation, is providing data to assist the decision makers with the choices before them.

Assuming that the trees can be cut every four years using a pollard cutting system, two main products can yield substantial biomass and income to Valley residents. Wood in the form of construction poles and fuelwood could bring in about $880./km on the first cut. In subsequent years, income would be about $270./km on an annual basis.

If we take both the wood and the grain benefits that the farmer could recieve from the windbreaks, he could conceivably increase his annual income by about about 30 percent. This is a considerable advantage to a people who are hardened to the fact of eeking out a subsistence from one year to the next.

And there are other benefits as well; ones that are much more difficult to quantify. Some of these include an overall environmental improvement: soil stabilization on Valley slopes due to fewer incursions for the wood supply there; increase in shade for animals thereby creating a better opportunity for buildup of soil nutrients; a slowing down of soil degredation due to the absence of fallow in the region; and perhaps most important, an increase in pride on the part of the farmers in the area. They do _realize_ the benefits, and they have more hope in their own lives because of the windbreaks that criss-cross their Valley.

COMPETITION BETWEEN A WINDBREAK AND AN IRRIGATED CROP (1)

M. Mechergui; H. J. Mellouli (2)

ABSTRACT

The objective of this research was to study the competition for soil water between the trees making the windbreak (Cupressus sempervirens) and an irrigated crop (Medicago sativa).

We evaluated the competition between the windbreak and the crop by the use of the water budget method to:

- Find the maximum distance beyond which the competition was nonsignificant.
- Study the effect of the windbreak on the crop yield and on the real evapotranspiration (ETR).
- Study the effect of spatial variability of soil characteristics on the above.

For this purpose 33 measuring sites were installed. At each site were located tensiometers for measuring the water potential variation and neutronic access tubes for measuring the volumetric water content. The tubes were located 1/2 meter apart for the first 3 meters and 1 meter apart for another 27 meters.

To accomplish the objectives, the spatial and temporal variations of water content were calculated. The results were in accordance with the findings previously reported in the literature. The bulk density of the soil indicated that the roots of the trees in the windbreak extended about 9 meters into the field. The plotting of yield as a function of ETR indicated three zones:

*high ETR with low yield (competition).
*high yield, low ETR (positive effect of windbreak).
*intermediate zone.

The real consumptive use was variable being a function of distance from the windbreak and this allowed us to find a new method of partitioning the water applied.

LITERATURE REVIEW

A number of reviews of research on the influence of windbreak on adjacent crops have appeared in the literature: Jensen (1954), Van Eimern et al. (1964), Guyot (1963), Rosenberg (1967, 1975, 1979), and Sturock (1975). All agree that the windbreak has a big effect on all climatic factors and plant factors.

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The windspeed varies with distance from the windbreak as shown by Eimern (1964). The ETP (potential evapotranspiration) is directly affected by this variation, Guyot (1963). The relative proportion of water transpired to that evaporated may also be increased (Budyko, cited by Van Eimern 1964). Burrows (1970) found that crop production per unit of water consumption was either improved or was not affected in the sheltered area. There is water conservation as was shown by Marshall (1967). One might conclude from the literature that the climatic factors have been largely studied; however, little has been done on spatial variability of soil water retention caused by the presence of the windbreak. Little is known about the competition between the crop and windbreak. This competition was detailed in our study using soil physical concepts in nonsaturated zone and principles for estimating water budget.

EXPERIMENTAL DESIGN

The ETP can be estimated by the Penman formula. This formula uses many climatic factors (radiation, windspeed, air temperature, air humidity). Much effort and equipment is necessary to get data on those parameters. This experiment was designed to study the ETR and the ETP but by using only one factor which is the water content in the soil. This is possible if we use the neutronic probe and tensiometers. Fig. 1 shows the experimental design for locating the access tubes.

From data obtained utilizing these tubes, we can calculate the volumetric water content and then calculate the stock of water. The ETR can be deduced by using the method of water budget.

In addition to this parameter, the bulk density was measured by utilizing the gammametric probe. Crop yield (dry and green matter) was determined by weighing the crop harvest. The crop studied was alfalfa (<u>Medicago sativa</u>). Three irrigations were used in August with the schedule of:

- *August 8, 1985 40 mm/ha
- *August 14, 1985 60 mm/ha
- *August 28, 1985 100 mm/ha

The windbreak consisted of two rows of <u>Cuprussus sempervirens</u> (8 m high) and <u>Acacia eburnea</u> (4, 5 m high). The experiment was conducted in Tunisia 30 miles from Tunis on a silty-clay soil.

RESULTS AND DISCUSSION

<u>Spatial variability of bulk density of the soil</u>: To have the volumetric water content, we need to calibrate the neutronic probe by measuring bulk density. In each site this parameter is measured as a function of depth (every 10 cm). The values are presented in Fig. 2. In all 33 plots, bulk density increased with depth. The bulk density as determined from measurements in the first 12 tubes (first 9 meters from the windbreak) at any depth was less than found in all of the remaining tubes. The windbreak can have a big effect on soil structure in particular by reducing bulk density as demonstrated by the variation found in the distance up to 9 meters. In terms of water, it may be that the competition can go to 9 meters.

Spatial variability of the stock of water: *During the rainy period, 172 days after planting alfalfa and at the end of the winter (April 30), the stock of water in the soil was measured and is presented in Fig. 3A. There is a big effect of the windbreak on the partition of the water (from natural rainfall). Fig. 3B shows the stock of water before the experiment was initiated. There was a high consumptive use near the windbreak followed by a decrease and then at 20 meters it increases again. *During irrigation period: Fig. 4 and Fig. 5 indicate the stock of water in the soil as a function of distance from the windbreak. In Fig. 4 we find the stock 2 days after irrigation and stock just before the next irrigation, however, we measured water stock each day with three of the measurements recorded in Fig. 5. In all of the curves cited, the stock is maximum in the middle and decreases slowly toward the edges. The curve of the stock of water just before any irrigation is not symetric. With function of time the stock decreases rapidly near the windbreak.

Real evapotranspiration: *Fig. 6 shows the evolution of ETR with distance from the windbreak for the entire cycle of alfalfa (between cuts) in August. The ETR of the reference plot is also plotted (257 mm). The consumptive use (competition) for 9 meters between the crop and the windbreak, is similar to the value found in the spatial variability of bulk density. The ETR curve is not symetric as was also found in the analysis of the water stock. *Fig. 7 gives the yield or production (dry and green matter) of the alfalfa crop. There was an exponential increase in yield with each meter as you first left the windbreak and then a slow linear increase. The reference yield is 1, 78 kg/m2 delineating the two zones: high ETR and low yield; low ETR and high yield. The distance from the windbreak was 7,5 m, almost the same as found before.

*The yield per unit of m3 of ETR is plotted in Fig. 8 giving a limit of competition at 10 meters.

*Fig. 9 illustrates the yield with function of ETR and indicates three response zones:

+The competition zone between zero and 4 meters (0.5 H) where ETR is high and yield is low; it is represented by:
ETR (mean) = 1, 6 ETR (reference)
yield (mean) = 0, 73 yield (reference)
+intermediate zone between 4 and 9 meters:

$\overline{\text{ETR}}$ = 1, 15 ETR

$\overline{\text{yield}}$ = 0, 9 yield

+No competition after 9 meters
ETR increases
yield increases

In taking into consideration the reference plot, we can calculate the consumptive use of the windbreak. It is 1, 48 m3 per linear meter of windbreak, a value that in August, is six times the consumptive use of 1 meter square of alfalfa. Since there is an inequality in the consumptive use of water as a function of distance from the windbreak, the 113 stock left at the end of the cycle per linear meter (lm) of windbreak, after substracting the common stock is 1, 65 m3/lm. The windbreak needs 1, 5 m3/lm. For this reason we need a new partition of the irrigation (less in the middle, more near the windbreak) to get the highest yield in the field.

CONCLUSION

The method used for determining the ETP adopted for sheltered area is based on many formulas. Those formula, like Penman require mainly the control of many climatic factors that are variable under the effect of windbreaks. The water budget method adopted here has the advantage using one parameter easy to measure: the volumetric water content. The results were similar to that found in the literature. The competition was high near the windbreak and can go to 9 meters. A new partition of the irrigation will correct this deficit without adding any supplement. How all these results vary with function of other crops; that is what should be done in the future.

(1) Contribution from the windbreak project in Tunisia
(2) Associate professor of water and soil science in the department of Amenagment and former graduate student at National Agronomic Institute of Tunis-Tunisia.

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Wind (North-West)

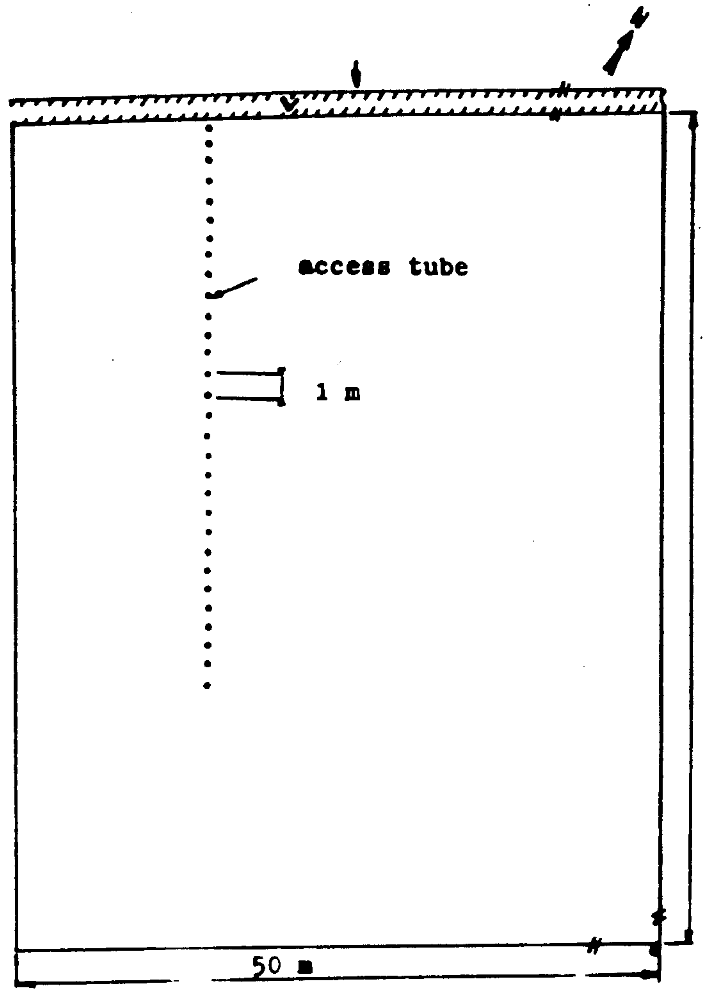

Figure 1: Experimental design.

Figure 2A: Bulk density variation with function of distance to windbreak for the depth varying from 0 to 55 cm.

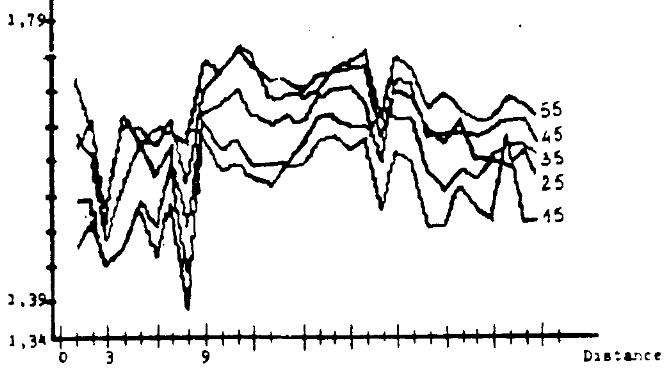

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Figure 2B: Bulk density variation with function of distance to windbreak depth varying from 65 to 105 cm.

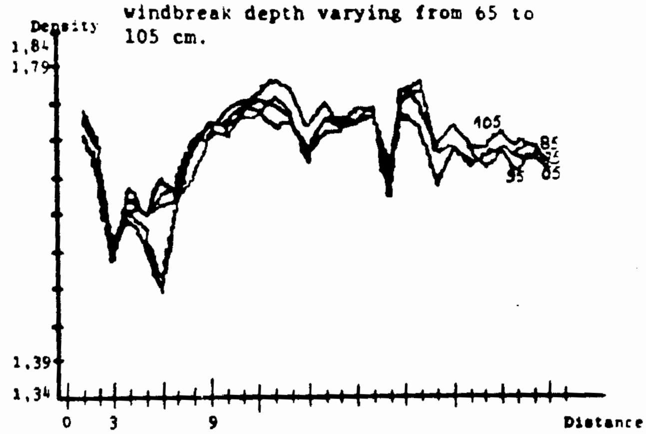


Figure 3A: Stock variation of water with function of distance to windbreak for 4-30-1985.

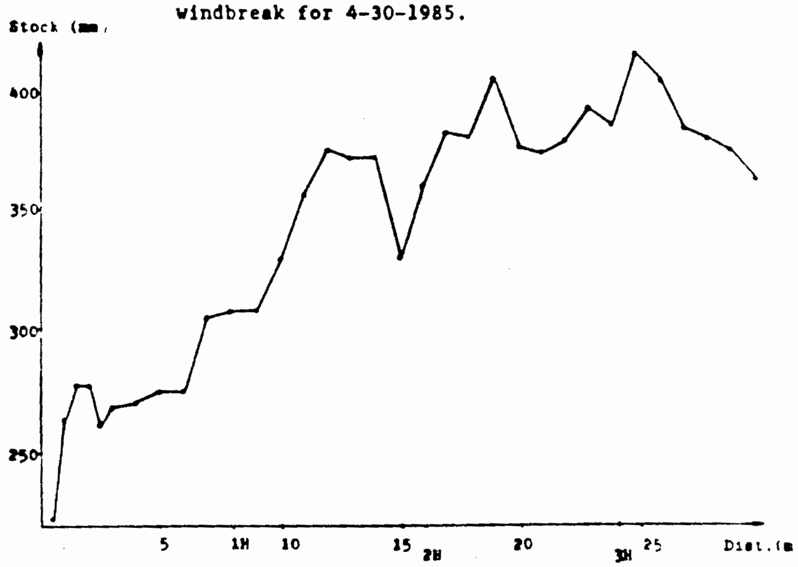
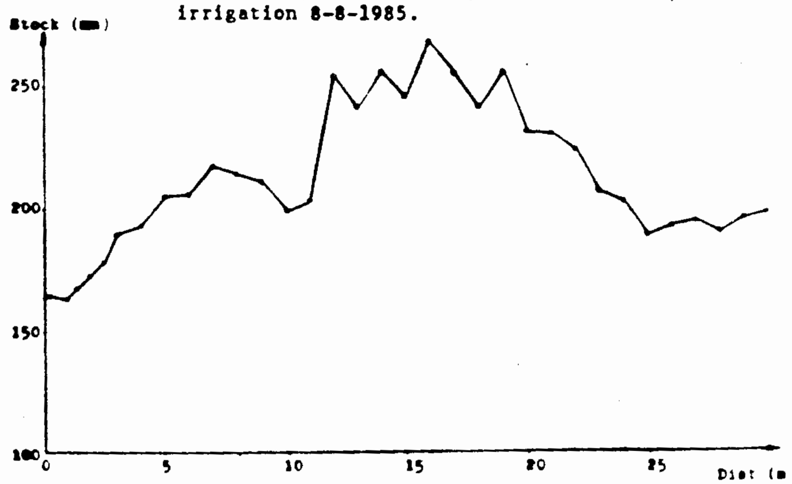


Figure 3B: Stock variation of water with function of distance to windbreak just before any irrigation 8-8-1985.



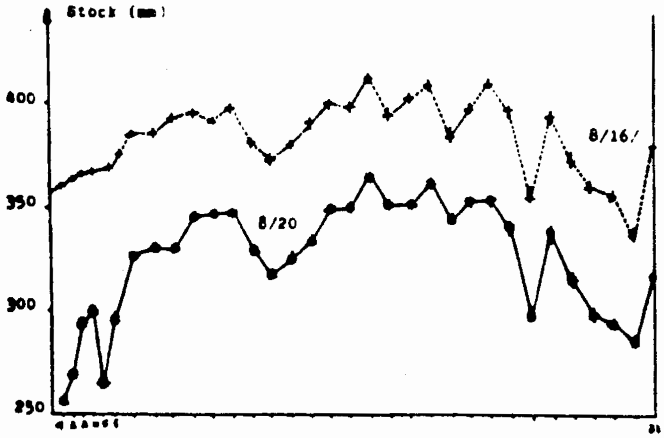


Figure 4: Stock variation of water with function of distance to windbreak.

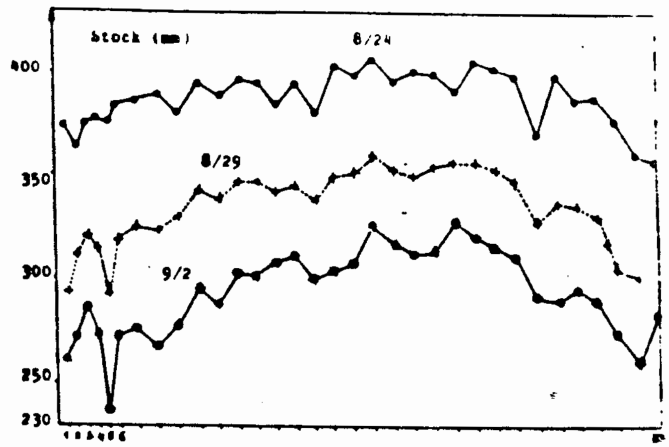


Figure 5: Stock variation of water with function of distance to windbreak.

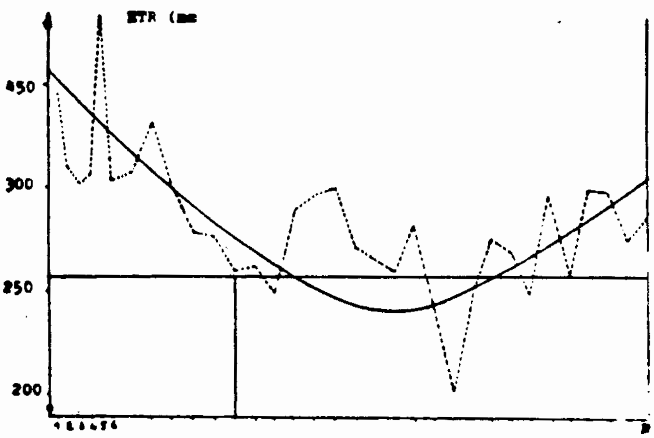


Figure 6: ETR variation with function of distance to windbreak.

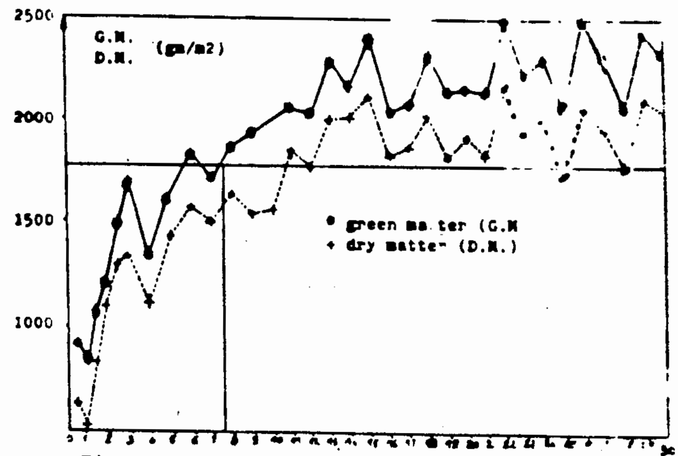


Figure 7: Green matter yield variation with function of distance to windbreak.

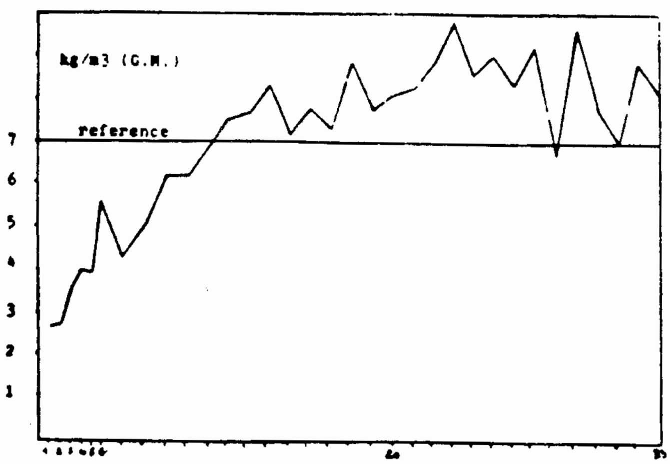


Figure 8: Yield of alfalfa per unit of consumptive use with function of distance to windbreak.

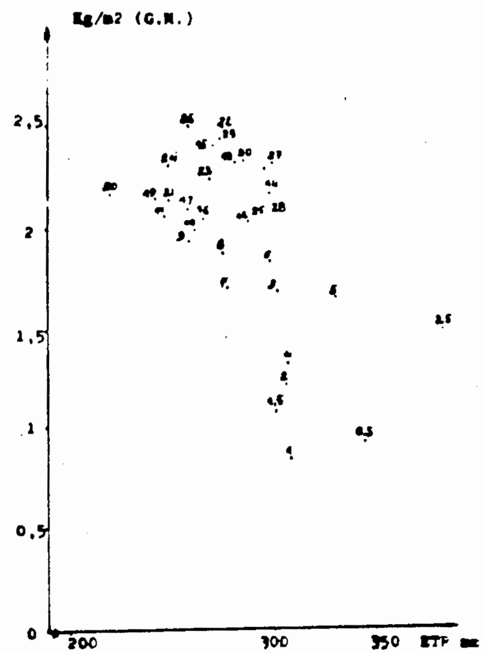


Figure 9: Relationship between the yield and ETR.

AN OVERVIEW OF WINDBREAKS IN THE UNITED STATES

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One of the largest windbreak planting programs in the United States, began with the creation of the Prairie States Forestry Project in 1935. With annual funds provided by Congress, 18,600 miles of windbreaks (217 million trees) were planted on 30,200 farms from 1935-1942. This effort occurred after the Dust Bowl days when Civilian Conservation Corp (CCC) and the Works Progress Administration (WPA) labor was available.

The Prairie States Forestry Project's biggest accomplishment was proving to the disbelievers that tree planting in the Plains states could be effective.

In the 1940's, World War II changed many priorities for the Department of Agriculture. The Defense Department needed both the manpower and the funds, formerly directed to the forestry project, to continue the war effort. So, for windbreak plantings to continue, the commitment had to come from the local level.

In 1942, the tree planting program was transferred by the Department from the Forest Service to the Soil Conservation Service reflecting this changing thrust. The SCS, working through the local conservation districts with the local land users, began promoting the installation of windbreak plantings in combination with other practices to conserve the soil and water resources.

The setting today is much like that in 1942 with the exception that technology for windbreaks has increased. Windbreak designs currently have fewer rows than the massive shelterbelts planted after the Dust Bowl days. Fewer rows were found to be just as effective for controlling wind erosion when designed to fit the cropping system, and less land was taken out of production.

Today, more agencies, organizations, and individuals are directly or indirectly involved with windbreaks. There is probably no better example of the interests in windbreaks than the variety of organizations making presentations here this week.

Within the Department of Agriculture, the Extension Service provides educational programs that enables individuals to recognize and solve problems dealing with trees and shrubs in shelterbelts. Extension is responsible for disseminating research, transferring technology and helping to identify areas of needed research.

Forest Service research helps provide fundamental knowledge and technology affecting windbreaks. Surveys are conducted to detect insect and disease infestations. Results of the surveys also help determine the necessary measures to control or suppress the insects or disease conditions.

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Agricultural Stabilization and Conservation Service administers cost share programs, such as Agriculture Conservation Program and the Conservation Reserve Program, for providing financial assistance to landowners to plant windbreaks. Working through county committees, ASCS shares the cost of establishing and renovating windbreaks.

The Agricultural Research Service is a research arm of the Department whose mission is to develop improved knowledge, concepts and practices that permit greater beneficial uses of soil, water, and air resources. Within the National Research Program, ARS has an objective to improve wind erosion prediction and control techniques to protect crops and soils.

As I stated before, since the 1942 transfer of responsibility to SCS for windbreaks and shelterbelts, SCS has been working through the local conservation districts to assist landowners and operators plan and design their windbreaks. Emphasis is placed on planting species adaptable to the soil, climate, and management objectives of the land user. SCS does administer the Great Plains Conservation Program which provides both technical and financial assistance to landowners in their efforts to reduce soil loss from wind and water erosion. Finding suitable plants for erosion control on sites where establishing vegetation is difficult is a major emphasis of the Ecological Sciences Division's plant materials program.

The General Accounting Office issued a report in 1975 stating that unless actions were taken to encourage farmers to preserve rather than remove windbreaks, an important resource that has taken years to develop could be lost and adjacent cropland damaged. In response to that report, SCS agreed to survey five Great Plains states for windbreak removals from 1970-1975. Several conclusions were drawn from this survey.

First, there is a definite trend away from wide field windbreaks and towards narrow windbreaks. Results indicate a 2.4 percent decrease in length of wide windbreaks (over 50 feet in width) and an increase of 8.8 percent in length of narrow windbreaks (less than 26 feet wide).

Second, removal of field windbreaks was more than offset by new plantings in states north of Oklahoma. Although 1,154 miles of windbreaks were removed from 1970-1975, there was a net gain of 682 miles, an increase of 1.8 percent over the 1970 figure.

To increase and maintain planting and renovation of windbreaks, the federal (USDA) agencies must continue their effort in cooperation with other interested organizations. These include the Great Plains Agricultural Council, Conservation Districts, State Foresters, Fish and Wildlife Departments, Universities and Colleges, and State Experiment Stations, to name just a few.

Where are we today? The 18,600 miles of windbreaks planted during the Prairie States Forestry Project are now part of the nearly 170,000 miles of windbreaks currently in this country. Yes, we are still actively establishing windbreaks. Since 1942, we have averaged better than 2000 miles of windbreaks per year. This compares to 2325 miles per year during the project years.

But, are these 170,000 miles of windbreaks adequate to reduce soil blowing, control snow deposition, conserve moisture, protect crops, orchards, livestock, and wildlife? The February 1986 report of wind erosion conditions in the 10 Great Plains states indicated that 3.3 million acres of land was damaged by wind through the end of February. Of this damage, 94 percent occurred on cropland. On land not damaged by wind, crops or cover was destroyed on 216,000 acres. In addition, 17.1 million acres of land were reported in a condition to blow.

So in summary, we can say, the past 50 years show remarkable progress in planting windbreaks for conservation. Agencies, organizations, and individual land users should be proud of their accomplishments. However, this is not the time to "rest on our laurels". . . as stewards of the soil, we still have a job to do.

1. Droze, Wilmon H., 1977. "Trees, Prairies, and People." Published by Texas Women's University Press, Denton, Texas, 313 pp.

2. USDA, Secretary's Memorandum No. 1933, 1978. "USDA Interagency Agreement on Forestry."

3. 96th Congress, 2nd Session, Committee Print, 1980. "Compilation of Statutes Related to Agriculture and Forestry Research and Extension Activities and Related Matters."

4. USDA-SCS, 1982. "National Resources Inventory Statistics."

5. USDA-SCS, 1986. "Wind Erosion Conditions - Great Plains."

6. USDA-ARS, 1982. "Soil, Water, and Air Sciences Research." 1982 Annual Report.

7. USDA-SCS, 1980. "Field Windbreak Removals in Five Great Plains States, 1970-1975."

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STATUS OF WINDBREAKS IN THE UNITED STATES

Gary Nordstrom
USDA-Soil Conservation Service
Washington, DC

ABSTRACT

Windbreaks have been an important conservation practice for controlling wind erosion and protecting rural farmsteads since the dust bowl days of the 1930's. Beginning with the Prairie States Forestry Project, thousands of acres of field and farmstead windbreaks have been planted every year. In the past decade concern has been expressed that there has been a significant loss of windbreaks in the United States.

This paper examines the status of windbreaks as reported in the 1982 National Resources Inventory conducted by the Soil Conservation Service. Data reported are the total number and acres of windbreaks present as of 1982. Other characteristics such as average length and width as well as the geographical distribution of windbreaks are examined.

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SECTION III

1452041 A8007-01264 2
Shelter boosts crop yield by 35%.
Sturroch, J. W.
DSIR, Christchurch, New Zealand.
New Zealand Journal of Agriculture, 1981, 143,3, 18-19
Languages: En
1 fig.
An experiment conducted under practical farming conditions to determine the value in relation to grain yield of windbreaks showed an average increase of 35% at distances from the windbreak of between 1 and 6 times its height. The windbreak had a negligible effect on yield beyond this distance, while there was a notable depression in plant height and, correspondingly, weight at 1 h which was assumed to be the result of competition from the trees. Improvement in the water relations of plants was also indicated.

1418947 F0043-00900 1
Protection of irrigated lands by forest belts.
Stroyanaya, S. A.
Boyarskaya LOS, Ukr. Sel'skokhoz. Akad., Kiev, Ukrainian SSR.
Vestnik Sel'skokhozvaistyennoi Nauki, Moscow, USSR, 1981, No. 6, 75-83
Languages: Ru Summary Languages: en
16 ref.
Data are presented on: the ht, of various shelterbelt species at 20-30 yr old; and max. recommended field sizes on chernozem and dark chestnut soils.

1414003 Z0003-00081 0
The role of shelterbelts for soil protection in agriculture in Kazakhstan.
Vasil'ev, M. E.
Lesnoe Khozyaistvo, 1979, No. 5, 36-39
Sec Jnl Source: Soils and Fertilizers 44, 1436.
Languages: Ru
A mathematical model was developed for the total braking aerodynamic effect of a shelterbelt/stubble system. Data are presented in histograms and tables for various types of shelterbelts (semi-permeable, permeable, and open) and fields with and without stubble, showing: the reduction in wind speed and evaporation from the soil, snow advection, the snow sublimation balance, the total snow balance, wind erosion, and yield of spring wheat. The results show that permeable shelterbelts and stubble left on the fields create the best conditions for soil moisture and give the greatest yields of grain.

use of windbreaks.
Lynch, J. J. ; Donnelly, J. B.
Division of Animal Production, CSIRO, Pastoral Research Lab., Armidale, NSW 2350, Australia.
Australian Journal of Agricultural Research, 1980, 31,5, 967-979
Languages: En
22 ref.
Between 1964 and 1969 in New South Wales, 88 Peppin ewes were grazed continuously on pastures, predominantly of Phalaris aquatica and Trifolium repens, at 15, 30 or 37.5/ha for 5 years. The paddocks were either square or rectangular in shape with fences of sheet iron or wire. In the square paddocks the sheet iron fences acted as a windbreak providing protection for plants and animals. In the first 2 seasons when rainfall was well below average, sheep in sheltered paddocks at 37.5/ha had slightly greater production (liveweight gain and annual wool yield) than the others; at 15/ha the productivity of the sheltered sheep was much greater. During the remaining 3 seasons there was no large difference among treatments in herbage production or animal production at the lowest stocking rate; at the highest stocking rate sheep in sheltered paddocks had much greater production than those in unsheltered paddocks. At 30/ha there was greater plant and animal productivity from sheltered paddocks during the last 2 years of the experiment.

1343558 F0042-03713 1
Increasing the resistance of stands of Ulmus pumila var. arborea in the dry steppes.
Godnev, E. D.
Lesnoe Khozyaistvo, 1980, No. 7, 34-37
Languages: Ru
10 ref., 1 pl.
In the large shelterbelt schemes in the dry steppe regions of the south-east of the RSFSR, the main species used (U. pumila var. arborea) generally tends to die by age 14-16 yr. Data are presented on the condition of some important shelterbelts, and on the increment of the trees. After the death of most of the trees at 14-16 yr, the few surviving trees show increased increment. Trials have been made at rehabilitating belts by clear-felling to obtain coppice regrowth; also, intensive mechanical weed control and soil-loosening have been tried, the aim being to improve the moisture supply. The results indicate that the young coppice and sucker regrowth must be heavily thinned and the soil intensively cultivated in order to achieve satisfactory rejuvenation. The target should be to have 800-900 small patches per ha, each containing only 1-2 of the strongest and most vigorous suckers or coppice shoots.

1333994 00034-05603 1
Influence of windbreak-shelter on dry matter accumulation and partitioning in soybeans.
(Abstract).
Agronomy Abstracts. 72nd annual meeting, American Society of Agronomy.
Ogbuehi, S. N. ; Brandle, J. R.
Nebraska Univ., Lincoln, NE 69101, USA.
Publ: Madison, Wisconsin, USA; American Society of Agronomy.
1980, 89
Languages: En
A study was conducted during the 1978 and 1979 growing seasons to quantify the effect of windbreak-shelter on DM accumulation and partitioning in soyabean cv. Wayne. The rate and the amount of DM accumulation, as well as grain yield, were significantly increased with shelter. The size of the plant at flowering, number of pods/plant, number of seeds/pod, pod filling period and harvest index were important determinants of grain yield. Grain yield in the sheltered plots was 20 and 26% higher than that of the exposed plots in 1978 and 1979, resp. The close relationship between grain yield and plant ht., LAI and vegetative dry wt. suggests that accurate prediction of soyabean grain yield response to shelter can be made using any of these growth indices.

1333614 00034-05203 1
Effects of wind protection on winter survival of wheat in eastern Nebraska.
(Abstract).
Agronomy Abstracts. 72nd annual meeting, American Society of Agronomy.
Brandle, J. R.
Nebraska Univ., Lincoln, NE 68583, USA.
Publ: Madison, Wisconsin, USA; American Society of Agronomy.
1980, 97
Languages: En
In 1965, six 40-ac windbreak systems were established to investigate the effects of wind protection on survival and yield of winter wheat cv. Centurk. By 1975 the windbreaks had reached an effective ht. of 17 ft and provided some protection for the entire study area. During subsequent yr when winter temp. were below normal, significant increases in yields were recorded. Under near normal or above normal winter conditions, insignificant increases in yield were reported. Windbreaks reduced wind speed significantly, allowing snow to be deposited across the protected areas. Little snow was accumulated on unprotected areas, leaving plants exposed to extreme temp. and susceptible to winter kill.

1329428 F0042-02887; S0044-06352 1
Effect of mineral fertilizers on the growth and resistance of oak
Grimal'skii, V. I. ; Lozinskii, V. A.
Lesnoe Khozyaistvo, 1979, No. 8, 64-66
Languages: Ru
2 ref.
An account is given of fertilizer trials started in 1972 in a shelterbelt of oak (Quercus robur) in the Kiev region (forest steppe zone). The belt consisted of 12 rows, the oak alternating with rows of shrubs, 1.5 m between the rows, mean ht. of the oak 2.5 m, age 12 yr. The soil was a medium derno-podzolic sandy loam, previously arable. NPK (105/80/75 kg/ha) was applied in June 1972, more PK in Sept 1972, and N in May 1973 and May 1975. Details are given of foliage analyses, ht. and diam. increment, and insect damage to the leaves. The fertilizer treatment significantly improved the physiological condition and growth of the oak, but did not improve its resistance to defoliators (here mainly Euproctis chrysorrhoea).

1319728 00034-04466 1
Effect of windbreaks on the improvement of microclimatic conditions in paddy fields.
Tomari, I. ; Ishiguro, T. ; Fujiwara, T.
Hokkaido National Agric. Exp. Sta., Hitsujigaoka, Sapporo, Japan.
Research Bulletin of the Hokkaido National Agricultural Experiment Station, 1980, No. 127, 31-76
Languages: Ja Summary Languages: en
51 ref.
In trials with windbreaks consisting of trees, wind velocity was decreased 70-80% at 50 m from the windbreak and the effective distance was 10-15 times the windbreak ht. Water temp. in paddy fields was increased 3-4 deg C at 50 m from the windbreak and water flow led to equalized temp. Effects on air temp., temp. of stems and leaves and yield were also found. Plastic net windbreaks reduced wind velocity by 50-60% at 10 m from the windbreak and increased water temp. more than the windbreak consisting of trees. Effects on leaf and stem temp. and air temp. were similar to those of windbreaks consisting of trees. Effects on growth and yield were found at up to 80 m (40 times the windbreak ht.) from the windbreak. A windbreak consisting of 3 surfaces to deflect the wind upwards reduced wind velocity by)50% at 5 times the windbreak ht. away from it. Water temp. increased markedly and the equalizing effect of water flow was greater than with other windbreaks.

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1303728 00034-03384 1
Shelterbelt protection. Its effect on soyabean yields.
La proteccion con rompevientos su incidencia sobre la productividad de la soja.
Zeljkovich, L. T. de ; Coca, M. G.
Estacion Experimental Regional Agropecuaria, Pergamino, Argentina.
Informe Tecnico, Estacion Experimental Regional Agropecuaria Pergamino, 1979, No.157, 16
Languages: Es Summary Languages: en
15 ref.
In field trials in 1975-8 at Pergamino on a lightly eroded Pergamino soil, soyabean cv. Lee was grown in plots unprotected or protected with shelterbelts 70 m long and 2 m high orientated E.-W. against the prevailing N. wind. The shelterbelt was plastic sheeting in 1975-6, Castilla cane (Arundo donax) in 1976-7 and rows of maize cv. Abati II sown 2 months before the soyabeans in 1977-8. Evaporation, wind speed, soil temp. and rainfall were recorded throughout the trials. In 1975-6 the soil temp. was 0.2-2.5 deg C higher on still days and 0.7-3.3 deg C higher with the N. wind in the protected than the unprotected plots; soil temp. were not significantly different in the following 2 seasons. In 1975-6, germination and flowering were earlier and seed yields significantly higher (2.14 and 1.59 t/ha) in the protected than the unprotected plots. The 2 growing seasons in 1976-8 were characterized by heavy rains and the growth and seed yields of protected and unprotected plots were not significantly different.

1286444 F0042-01478 1
Sloped canopy shelterbelts.
Harris, J. W.
New Zealand Farmer, 1979, 100,12, 10-12
Languages: En
A forest farming system is described with a triple rotation of arable, shelterbelt and pasture. Shelterbelts are established 50 m apart (at centres), running E.-W. (winds in New Zealand are mainly N.-S.) with a canopy sloping southwards to a strip of arable land about 14 m wide; spacing is at 2.5 m with 2 m between rows. Every 3 yr a row is planted to the S. (shaded side) of the belt, and the 2 m of arable lost is replaced from the adjoining pasture. Trees on the N. (sun) side of the belt are high pruned for quality timber and to enable the pasture to extend underneath. Initial establishment might involve a fast-growing species to the N. (radiata pine), medium rate (Cryptomeria japonica) in the middle and slow growing (Abies pinsapo) to the S.; thereafter radiata pine would be planted. Anticipated yield (80 mature knot-free stems/ha plus 80 thinnings every 6 yr) over a 27-yr rotation is over half that expected from forestry alone.

sorghum.
Reddy, M. G. ; Kulkarni, G. N.
Univ. of Agric. Sci., Dharwar 580 005, Karnataka, India.
Annals of Arid Zone, 1978, 17,4, 343-347
Sec Unl Source: Field Crop Abstracts 33, 6141.
Languages: En
3 ref.
In irrigated trials in the semi-arid tract of Dharwar, Karnataka, sorghum hybrid cv CSH-1 protected from winds with a shelterbelt of bamboo mats 2.5m high gave grain yields of 4.15 t/ha, compared with 3.72 t without a shelterbelt. The moisture depletion during the crop period was 13 mm less in protected plots than in unprotected ones.

1264896 S0044-01436; A0006-00585 3
The role of shelterbelts for soil protection in agriculture in Kazakhstan.
Vasil'ev, M. E.
Lesnoe Khozyaistvo, 1979, No. 5, 36-39
Languages: Ru
A mathematical model was developed for the total braking aerodynamic effect of a shelterbelt/stubble system. Data are presented in histograms and tables for various types of shelterbelts (semi-permeable, permeable, and open) and fields with and without stubble, showing: the reduction in wind speed and evaporation from the soil, snow advection, the snow sublimation balance, the total snow balance, wind erosion, and yield of spring wheat. The results show that permeable shelterbelts and stubble left on the fields create the best conditions for soil moisture and give the greatest yields of grain. 'dagger'

1263075 00034-00696; G0051-00432 1
Effectiveness of fertilizers applied to fields protected by forest strips.
Danilov, G. G. ; Kargin, I. F. ; Shiriyazdanov, N. M.
Mordovskii Pedinstitut, Saransk, USSR.
Agrokhimiya, 1980, No.1, 52-57
Languages: Ru
16 ref.
The effectiveness of the same rates of N, NP and NPK in increasing grain yields of winter wheat and fresh fodder yields of vetch/oat mixture and maize in NE Russia was higher when applied to fields protected by forest strips than when applied to unprotected fields. The forest strips improved the microclimate and soil m.c. The effective distance of the wind break from the crop was up to 25 times the windbreak ht.

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1259079 F0042-00650; S0044-01435 1
The protective action of a single shelterbelt against wind erosion.
Dzhodzhov, Kh. ; Georgiev, G. S.
Inst. po Pochvoznanie, Sofia, Bulgaria.
Gorskostopanska Nauka, 1980, 17,1, 60-64
Languages: Bg Summary Languages: ru, en
5 ref.
Investigations were made on the protective effect of a single-row shelterbelt of coppiced Robinia pseudoacacia (ht. 9 m, width 2 m) of permeable structure, in Bulgaria. The belt was protecting a field of sugar beet, and during a dust storm with winds of up to 12-17 m/s in 1978, it exerted a significant effect in preventing wind erosion and blow-out of the crop for a distance equal to 28-30 times its ht. The yield of sugar beet on the area protected by the belt was 32% greater than that obtained by re-sowing unprotected areas after the storm, and the sugar content of the protected crop was 1% greater.

1179516 Q0033-06141; S0043-06791 1
Effect of shelter belt on water use and yield of CSH-1 sorghum.
Reddy, M. G. ; Kulkarni, G. N.
Univ. of Agric. Sci., Dharwar 580 005, Karnataka, India.
Annals of Arid Zone, 1978, 17,4, 343-347
Languages: En
3 ref.
In irrigated trials in the semi-arid tract of Dharwar, Karnataka, sorghum hybrid cv CSH-1 protected from winds with a shelterbelt of bamboo mats 2.5m high gave grain yields of 4.15 t/ha, compared with 3.72 t without a shelterbelt. The moisture depletion during the crop period was 13 mm less in protected plots than in unprotected ones.

1176098 F0041-04656 1
The role of shelterbelts for soil protection in agriculture in Kazakhstan.
Rol' lesnykh polos v pochvozashchitnoi sisteme zemledeliya v Kazakhstane.
Vasil'ev, M. E.
Lesnoe Khozyaistvo, 1979, No. 5, 36-39
See Also: 1176097 F0041-04655
Languages: Ru
A mathematical model was developed for the total braking aerodynamic effect of a shelterbelt/stubble system. Data are presented in histograms and tables for various types of shelterbelts (semi-permeable, permeable, and open) and fields with and without stubble, showing: the reduction in wind speed and evaporation from the soil, snow advection, the snow sublimation balance, the total snow balance, wind erosion, and grain.

1176097 F0041-04655 1
Shelterbelts on the virgin lands.
Polezashchitnye lesnye polosy na tselinnykh zemlyakh.
Vekshegonov, V. Ya.
Lesnoe Khozyaistvo, 1979, No. 5, 33-36
Languages: Ru
3 pl.
A review of experience gained with shelterbelts as part of the scheme for large-scale introduction of agriculture into the virgin lands of the USSR since the 1950s, with special reference to the northern part of Kazakhstan. Examples are given of appropriate lay-out of shelterbelts, and of the increases in grain yields achieved as a result of shelterbelts. The density of planting and moisture requirement of the trees (mainly Betula verrucosa (B. pendula) and Populus balsamifera) are discussed, and some general recommendations are made on shelterbelt establishment and management in this region.

1172466 Z0001-02215; S0043-06609 1
The controlling of desertification in the oasis in Dunhuang.
China's deserts and the prevention of desertification.
Academia Sinica, China, Lanzhou Institute of Desert Research
1979, 55-58
Languages: Ch Summary Languages: en
Dunhuang County is situated in the westernmost Hexi Corridor in Kansu Province. It covers an area of more than 2000 km2, of which the oasis is 0.4%, the rest being gravel gobi and sand dunes. The oasis in Dunhuang has a temperate arid climate with average annual precipitation of 29mm. Irrigation comes from Dang River and spring water. The oasis has a history of more than 2000 years of human occupation. As a result of human activities during this long period, the natural vegetation has almost been destroyed, desertification of the land is serious, and wind and sand erosion extensive. In order to prevent desertification in Dunhuang, sand-control forest belts, tree patches and shelterbelt networks have been built along roads and canals and at the fringe of sand dunes and gobi for the past 20 years. Now the area of shelter forests amounts to over 2000 ha, thus forming a comparatively complete protective system. Under the protection of this system, the condition of the oasis has been improved and the yield of crops has been continually raised.

136

1151161 00033-04036 1
Effect of forest belts on grain yield and quality of high-yielding winter wheat cultivars of different ecological types.
Miloserdov, N. M.
Prisivashskaya Agrolesomeliorativnaya Opytnaya Stantsiya, Partizany, Kherson, Ukrainian SSR.
Doklady Vsesoyuznoi ordena Lenina Akademii Sel'skokhozyaistvennykh Nauk imeni V.I. Lenina, 1977, No. 3, 8-10
Languages: Ru
5 ref.
In Kherson region of the Ukraine, cultivation of winter wheat cv. Bezostaya 1, Kavkaz and Odesskaya 51 on fields protected by shelterbelts gava 5-yr av. grain yields of 3.5-3.79 t/ha, compared with 3.11-3.51 t when grown on unprotected fields. The extent of the effect of the wind break was 5-6 times the windbreak ht. Cv. Kavkaz was most responsive to the shelter of windbreaks.

1135102 00033-03770 1
Cropping systems progam. Component technology development and evaluation. Soil and crop management. Effect of time of planting cassava on upland cropping pattern performance.
Annual report for 1977.
Philippines, International Rice Research Institute
Publ: Los Banos, Laguna, Philippines; IRRI.
1978, 444-445
Languages: En
In a trial in June 1976-April 1977 at IRRI, (a) maize cv. DMR-2 and (b) upland rice cv. C-22 were intercropped, or (c) cassava cv. Malagkit was relay-planted into every other maize row while (d) soyabean cv. TK5 was sown in the vacant areas between rows and followed by (e) cowpea (Vigna unguiculata) cv. EG 2. Adequate NPK/crop was applied by methods considered suitable for each crop. The grain yield of maize was higher (2.48 t/ha) in rows uncombined with cassava than with cassava (2.02 t/ha). In treatments in which (c) did not lodge (a typhoon caused lodging in early plantings) and acted as a windbreak, (c) did not reduce the yield of (b). Early plantings of (c) reduced yields of (d) more than later plantings. Yields of (e) were greatly reduced by intercrops, especially with late planting of (c), which also suffered from intercrop competition and did not recover even after the rice harvest. It was concluded that the opt. planting date for (c) was 20 days after sowing (a) and 40 days after sowing (b), and that a more shade-tolerant cv. of (e) was required for intercropping of this crop with other crops. Yield data on all the crops are tabulated.

1114605 Z0001-00955 0
Effect of windbreaks on the water status of soil and yield of crops.
Nauchnye Trudy, Ukrainskaya Sel'skokhozyaistvennaya Akademiya, 1977, No. 203, 30-33
Sec Jnl Source: Field Crop Abstracts 32, 5999.
Languages: Ru
In trials in 1962-71 in W. Ukraine, increasing the ht. of trees and removing their lower branches increased the effective distance of the windbreak from the wheat crop and increased soil moisture accumulation and grain yields; yield increases at a distance of 1, 5 and 10 times the windbreak ht. were 30, 49 and 39%, resp.

1104445 F0041-00858; S0043-02793 1
Growth and yield of woody species in relation to soil moisture conditions.
Rost i produktivnost' drevesnykh porod v zavisimosti ot uslovii uvlazhneniya pochvy.
Lomakin, A. G. ; Stepanov, A. M. ; Torokhtun, I. M.
VNIALMI, USSR.
Lesnoe Khozyaistvo, 1978, No. 11, 35-39
Languages: Ru
Investigations were made of the effect of the soil moisture conditions on the growth of various tree species in a shelterbelt in the Volga/Akhtuba floodplain. The belt was established in 1963 with seedlings of Populus nigra, Ulmus pumila var. arborea and Fraxinus pennsylvanica, wildings of Salix alba, and acorns of Quercus robur. In summer, after the spring floods had gone down, the water table was at 2.5-3.5 m, falling to 4 m in autumn and 5.5-6 m in winter. In 1967 a levee was built which prevented the flood water from approaching the belt, and this resulted in a further lowering of the water table, but in 1969 an irrigation channel was constructed and seepage from this resulted in a rise in the water table. Data are presented in graphs and tables on the growth of the trees. Data are also given from other investigations on the increment of Populus nigra from 15 to 31 years of age in relation to depth of spring flooding. The results indicate that all the tree species react sharply to changes in water supply, the hygrophilic species reacting earlier than the drought-resistant species.

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1071393 F0040-04211 1
Black walnut at the Vladimirovka agro-forestry land improvement experiment station.
Orekh chernyi na Vladimirovskoi agrolesomeliorativnoi opytnoi stantsii.
Mayatskii, I. N.
Vladimirovskaya ALOS, Nikolaevskaya Obl., Ukrainian SSR.
Lesovodstvo i Agrolesomeliloratsiya, 1977, No. 48, 70-75
Languages: Ru
7 ref.
A study of the growth of black walnut (Juglans nigra), 16-35 yr old, in S. central Ukraine showed drought resistance and winterhardiness, resistance to pests, and vol. increment to be comparable with oak (Quercus robur). Black walnut is recommended for amenity and shelterbelt planting in the southern chernozem zone.

1053177 C0049-08348 1
The effect of a windbreak wall on strawberry growing.
Uber die Wirkung von Windschutzmauern auf Erdbeerkulturen.
Dapper, H.
Baumschulpraxis, 1979, 9,2, 68-69
Languages: De
4 ref., 1 fig.
In Teneriffe, Canary Islands, a wall 2.2 to 2.5 m high made of blocks with holes in them was built as a windbreak near a terrace on which strawberry cvs Lassen, Fresno and Tioga were grown. In the plots near the wall the soil and air temperatures were considerably lower. Yields from shaded plots were lower than from the rest of the area.

1036894 00032-05999; S0042-05572 1
Effect of windbreaks on the water status of soil and yield of crops.
Komarov, F. S. ; Kulish, N. P. ; Martynyuk, N. V. ; Shostachuk, A. S.
Nauchnye Trudy, Ukrainskaya Sel'skokhozyaistvennaya Akademiya, 1977, No.203, 30-33
Sec Jnl Source: Referativnyi Zhurnal (1978) 7.55.28.
Languages: Ru
In trials in 1962-71 in W. Ukraine, increasing the ht. of trees and removing their lower branches increased the effective distance of the windbreak from the wheat crop and increased soil moisture accumulation and grain yields; yield increases at a distance of 1, 5 and 10 times the windbreak ht. were 30, 49 and 39%, resp.

1025964 00032-05198; G0049-03151 1
Green fodders in the cereal/fallow crop rotation.
Turgaiskaya Opytnaya Stantsiya, Turgai, Kazakh SSR.
Korma, 1978, No.1, 39-40
Languages: Ru
In crop rotation trials in which cultivation of cereals was alternated with bare fallow alone and with windbreak strips of tall plants, yields of spring wheat grain were 1.14 and 1.65 t/ha, resp. Oats sown as a catch crop on bare fallow in July yielded 4.23 t fresh fodder/ha, but yields of spring wheat in the following yr were reduced. However, when oats were cut in 6 m wide strips and 0.5 m strips were left uncut to achieve snow accumulation, oat yields were decreased to 3.58 t, whereas wheat yields were increased to 1.71 t. This was established in field trials in 1970-4 in N. Kazakhstan and confirmed later in 3 other provinces of NE Kazakh SSR.

997055 G0049-02206 1
The effect of belts of trees on the production of the adjoining grassland.
De invloed van beplantingsstroken op de produktie van het aangrenzende grasland.
Altena, H. J.
Centrum voor Agrobiologisch Onderzoek, 6700 AA Wageningen, Netherlands.
Bedrijfsontwikkeling, 1978, 9,9, 751-753
Languages: Nl
7 ref.
Effects of shelterbelts of mixed Quercus spp., Betula spp., Sorbus aucuparia and Frangula alnus 8-10 m tall and 6 m deep on growth of adjacent grassland were investigated; the windbreaks ran N.-S. and NW-SE and the grassland consisted mainly of perennial ryegrass with some Agropyron repens, Holcus lanatus and Agrostis stolonifera. Herbage yields were reduced by at the most 10% in a 10-m strip on both the windward and leeward sides of the windbreaks; yield reductions did not always occur and were only partly attributable to the trees, other factors being increased poaching and uneven fertility. Herbage contents of CP and CF were not affected by distance from the windbreak.

138

996985 F0040-01937 1
Increased attention to shelterbelt forestry.
Bol'she vnimaniya polezashchitnomu lesorazvedeniyu.
Vekshegonov, V. Ya.
Lesnoe Khozyaistvo, 1978, No. 6, 31-35
Languages: Ru
4 ref.
A general review is made of experience in the southern regions of the USSR, and especially in the dry steppes of the S. Ukraine, on the establishment, management and benefits of agricultural shelterbelts. Data are presented on grain yields in unprotected areas and in areas protected by shelterbelts, and the overall cash benefits of shelterbelts are calculated.

983954 E0067-01971 3
Preliminary observations on the mealybug (Hemiptera Pseudococcidae) in Zaire and a projected outline for subsequent work.
Nwanza, K. F.; Leuschner, K. (Editors): Proceedings of the International Workshop on the cassava mealybug Phenacoccus manihoti Mat.-Ferr. (Pseudococcidae) held at INERA-M'vuazi, Bas-Zaire, Zaire, June 26-29, 1977.
Leuschner, K.
International Institute of Tropical Agriculture, Ibadan, Nigeria.
Publ: Ibadan, Nigeria; International Institute of Tropical Agriculture.
1978, 15-19
See Also: 983951 E0067-01968
Languages: En
1 fig.
Information is given on the nature of the damage caused by mealybug (Phenacoccus manihoti Matile-Ferrero) to cassava in Zaire, on the biology and dispersal of the pest and on proposed measures for its control. Damage includes destruction of terminal shoots and expanded leaves by sucking of sap (and possibly by the introduction of a salivary toxin) leading to short internodes, small leaves and sometimes die-back. The extent of tuber yield loss resulting from the poor general condition of the infested plants is not certain, but definite economic loss is caused by infestation since young leaves are used as food. The mealybug is parthenogenetic, each female laying 200-400 eggs, and a generation took 20-30 days to develop. The populations built up in the dry season, but mealybugs were hardly ever found in the rainy season. Dispersal occurrred through transport on infested planting material and by wind. Newly hatched crawlers moved to the shoot tip during the windiest part of the day (10.00-12.00 h) and were carried to a height of up to 4 m and to a distance of at least 20 m. Owing to its recent introduction into Zaire, P. manihoti appears to have no natural enemies in that country, and the possibility of bringing parasites or predators in from another country for biological control should be investigated. Breeding cassava varieties for resistance is another long-term control method that will probably be very effective altering the planting time of cassava so as to avoid November (since November planting results in tuber yield loss), soil moisture conservation, fertilisation, and mixed cropping (the second crop being one suitable to act as a windbreak) appear to be the best short-term measures. At present, the practical use of chemical insecticides should be confined to cuttings that are to be transported from an area of heavy infestation to some other area, although they may be useful in experimental work to determine the extent of yield loss and economic thresholds.

961765 E0067-01196 3
A sex attractant for the cottonwood crown borer, Aegeria tibialis (Lepidoptera: Sesiidae).
Underhill, E. W.; Steck, W.; Chisholm, M. D.; Worden, H. A.; Howe, J. A. G.
National Research Council of Canada, Saskatoon, Saskatchewan S7N OW9, Canada.
Canadian Entomologist, 1978, 110,5, 495-498
Languages: En
7 ref., 1 fig.
Sesia tibiale (Harris) (Aegeria tibiale) is a pest of poplars, including Populus deltoides, which is commonly grown for shade and as a windbreak in western Canada, and is especially injurious in cutting beds in nurseries. In field tests at 2 places in Saskatchewan in June-August 1976, adult males were strongly attracted to virgin females and to mixtures of (3Z,13Z)-3,13-octadecadien-1-ol and its acetate. Extracts of female abdominal tips yielded 2 fractions stimulatory to male antennae. These fractions corresponded to a C18 alcohol and a C18 acetate. Electroantennogram measurements using synthetic chemicals demonstrated that appreciable male antennal stimulation occurred only with C18 compounds having Z-unsaturation at positions 3 or 13, indicating that the synthetic sex attractant may be the natural pheromone of the sesiid.

139

953132 Q0032-00674; S0042-01031 1
Plant water relationships of spring wheat as influenced by shelter and soil water.
Frank, A. B.; Harris, D. G.; Willis, W. O. : Growth and yield of spring wheat as influenced by shelter and soil water.
Frank, A. B. ; Harris, D. G. ; Willis, W. O.
North Great Plains Res. Cent., USDA, Mandan, ND 58554, USA.
Agronomy Journal, 1977, 69,6, 906-910
See Also: 953131 Q0032-00673 S0042-01030
Languages: En
19 ref.
Data for leaf water potential, xylem water potential, stomatal diffusion resistance, canopy temp., soil water potential, soil water extraction and grain yield are reported for spring wheat cv. Waldron grown on sandy loam in 1973 and 1974, with or without slat-fence enclosures and with or without irrigation. The combination of shelter and irrigation gave a higher leaf water potential, lower canopy temp. and the most favourable water status and water-use efficiency. Shelter did not reduce water stress on dryland-grown plants that lasted from early earing to maturity. As soil water varies greatly from yr to yr in the N. Great Plains, crop responses to windbreak shelter will be uncertain.

915135 F0039-05022 1
Agricultural research and training project El-Kod and Giar. People's Democratic Republic of Yemen. Shelterbelt plantations in arid and extreme arid areas of the People's Democratic Republic of Yemen.
Costin, E. ; Dragsted, J. ; Balaidi, A. S. ; Bazara, M.
[FAO Report], 1976, No. PDY/71/516, 45 pp.
Languages: En
20 ref., 5 pl.
Recommendations are made for the design, establishment and maintenance of shelterbelts for the protection of agricultural crops, soil conservation, wood production and amenity. In trials with 17 species, Eucalyptus camaldulensis, Albizia lebbek, Casuarina equisetifolia and Conocarpus lancifolius were fast growing, Azadirachta indica and Parkinsonia aculeata gave good height increment and Tamarix aphylla showed good crown development. In addition, Thespesia populnea was considered to be suitable as a secondary species.

896419 Q0031-05726 1
Annual report 1975.
Jaarverslag 1975.
(Netherlands, Instituut voor Bodemvruchtbaarheid);
Instituut voor Bodemvruchtbaarheid
Publ: Haren, Netherlands; Instituut voor Bodemvruchtbaarhei-d.
1976, 154pp.
Languages: Nl Summary Languages: en
Rye sown in a square pattern gave good protection against

ionic form, Zn and Ni as negatively charged organic complexes, and Co probably occurred in colloidal form. The max. level of the soil disinfectant 1,2-dichloropropane that could be applied without causing ear malformation in winter wheat was 5 l/ha in autumn and (1 l/ha in spring. Split applications of N increased tuber yields of potatoes by 1.5-2 t/ha on light loam, but in winter wheat gave increased susceptibility to Septoria (Leptosphaeria) nodorum. Yields of cereals on marine clay soils with (4 p.p.m. Cu were not increased by applying Cu. Sugar beet given 140 kg N/ha grown on land given up to 40 t FYM/ha in alternate yr for 30 yr yielded most sugar, 7.7 t/ha, where most FYM was applied. The adverse effects of heavy dressings of sewage sludge containing high conc. of heavy metals on yield of oats were eliminated by applying 8 g CaO/l substrate.

892646 F0039-04027 1
The influence of shelterbelts on the weight and viability of cereal seed.
Ahrif skogarskjols a kornthunga.
Arsrit, Skograektarfelags Islands.
Kristjansson, K. K.
Publ: Reykjavik, Iceland.
1976, 23-26
Languages: Is Summary Languages: en
2 pl.
(See FA 17, 433) Seed yields of barley (7 summers), oats (4) and spring wheat (3) protected by birch (Betula alba) shelterbelts increased by an av. of 24-41% compared with unprotected yields. The greatest improvements occurred during poor summers. Shelterbelts improved the viability of seed; however, unseasonal frosts also affected seed viability making the shelterbelt effect less clear-cut. Recommendations are made for the silviculture and management of shelterbelts for crops in Iceland.

878541 F0039-03591 1
The agro-economic effectiveness of shelterbelts.
Agroekonomicheskaya affektivnost' lesnykh polos.
Lyubartseva, V. S.
Nikolaev. Oblast. Uprav. Sel'skogo Khoz., Ukrainian SSR.
Lesnoe Khozyaistvo, 1977, No. 9, 65-67
Languages: Ru

In the Nikolaev region of the Ukraine, the 32 000 ha of shelterbelts amount to 1.7% of the arable area in the two major zones, viz. ordinary chernozems and southern chernozems. The agricultural enterprises of the region are classified into 4 groups according to the % area of the shelterbelts: (I) 3.1% or more; (II) 3-2.1%; (III) 2-1%; and (IV) 0.9% or less. Statistics are tabulated on the areas and proportions of the belts in the various groups and zones, and on the yields of grain, winter wheat, sunflower and silage maize in 1972-74. The crop yields increased steadily with increasing % area of shelterbelts. For example, yields of silage maize in group (I) in the ordinary chernozem zone were 8100 kg/ha greater than in group (IV), and in the southern chernozem zone 3200 kg/ha greater. The grain and sunflower yields were 20-38% greater and silage maize yields up to 60% greater in areas with complete shelterbelt systems than in areas with few or no shelterbelts. Data are tabulated on the economic indices of the crops in relation to the % area of the shelterbelts.

868587 F0039-03151 1
Agro-economic evaluation of shelterbelts at the planning stage.
Agroekonomicheskaya otsenka lesnykh polos na stadii ikh proektirovaniya.
Mayatskii, I. N.
Vladimir. ALOS UkrNIILKhA, Ukrainian SSR.
Lesnoe Khozyaistvo, 1977, No. 9, 62-65
Languages: Ru
7 ref.

A method is proposed for evaluating the economic effectiveness of planned and existing shelterbelts in the USSR. The method is based on the weight and cash values of the crops, the additional yield resulting from shelterbelts, and the expenses involved in securing the additional production. Data are tabulated showing these parameters for a wide range of crops (wheat, maize, barley, sunflower, hemp, sugar beet, melons, vegetables, etc.), and econometric formulae are presented for calculating the agro-economic effectiveness of the shelterbelts. Data are tabulated on the agro-economic effectiveness of one ha of shelterbelt aged 3, 4, 5 . . . 35 years, for four different types of belt: 4-row oak (Quercus robur); 3-row oak; 4-row robinia (Robinia pseudoacacia); and 3-row walnut (Juglans regia). In the Vladimir region of the Ukraine, the most effective belts are 3-row oak belts.

Sheikh, M. I. ; Chima, A. M.
Pakistan For. Inst., Peshawar, Pakistan.
Pakistan Journal of Forestry, 1976, 26,1, 38-47
Languages: En
11 ref.

Wheat yields were measured in quadrats in 6 fields in the Peshawar and Mardan districts of Pakistan that were bounded on one side by a row of trees. The trees (poplar or willow, ht. 7-16 m) had not been planted specifically as windbreaks. The highest yields were obtained 10-20 m (perpendicularly) from the tree rows, the yield falling again at greater distances. Yields were below av. in quadrats 5 m from the tree rows; the decrease varied with the orientation of the row, and was presumed to be due to shading. It is concluded that the planting of suitably orientated windbreaks could protect crops and increase their yield. Reductions in grain yield close to the tree belt could be offset by the sale of timber.

846613 F1001-01013 1
Possible pulpwood resources for Northern Australia: Pulping characteristics of young Anthocephalus chinensis and Sesbania grandiflora.
Logan, A. F. ; Murphy, P. I. ; Phillips, F. H. ; Higgins, H. G.
Appita, 1977, 31,2, 121-127
Languages: En
13 ref. BLL

Trees of A. chinensis (age 21/2 yr) from a shelterbelt near Darwin gave sulphate pulps suitable for unbleached and bleached grades including off-set printing papers; yields were moderately low. Sulphate pulping of wood plus bark required more chemicals and gave lower yields. NSSC pulps of wood were suitable for corrugating medium and strong paper and paperboard products.. Trees of S. grandiflora (age 41/2 yr) from the Ord River Irrigation Area gave moderately low yields of sulphate pulp (without bark), suitable for a limited range of unbleached or bleached end products. NSSC pulps were suitable for corrugating medium but pulp yields were low and severe cooking conditions were required. Additions of A. chinensis wood (kraft and NSSC) and of S. grandiflora wood (kraft) improved the drainage rate of kenaf pulps.

845609 R0020-02640 3
Shelterbelts on peat soils.
Polezashchitnye polosy na torfyano-bolotnykh pochvakh.
Podzharov, V. K.
BelNIILKh, USSR.
Lesnoe Khozyaistvo, 1977, 3, 48-50
Sec Jnl Source: Forestry Abstracts 39, 1, 287.
Languages: Ru
Large areas of peatlands have been drained, cleared of forest vegetation and reclaimed for arable agriculture in Belorussia, but wind erosion, especially in the spring, has proved a serious problem in such areas. As strong winds can blow from any direction in the spring in Belorussia, shelterbelt layouts must give protection from all sides. Permeable belts, 3-5 rows wide, with few or no shrubs, are best. Poplars are among the most suitable species. Recommendations are given on belt layout in relation to road and drainage networks, belt design, choice of species, establishment and tending. Large planting stock is advisable because of the vigorous weed growth, but the best solution is to sow grasses in the belts and harvest as hay. Data are presented on costs and yields.

843641 F0039-02124 1
The effectiveness of narrow shelterbelts of various designs in protecting fields in the chernozem steppe region of the Ukraine.
Polezashchitnaya effektivnost' uzkikh lesnykh polos razlichnykh konstruktsii v usloviyakh chernozemnoi stepi USSR.
Pilipenko, A. I.
Ukrain. Sel'skokhoz. Akad., Ukrainian SSR.
Lesnoi Zhurnal, 1977, No. 3, 17-21
Languages: Ru
10 ref.
In investigations in the Ukraine in 1971-75 on 35 shelterbelts of various designs, relationships were established between, on the one hand, the silvicultural/mensurational indices of belts and their openness and permeability, and, on the other hand, their effectiveness in reducing wind speeds and in increasing soil moisture, and the yield of winter wheat in the adjacent fields. In general, the increase in yield as a result of the shelterbelt was almost the same, in absolute terms, irrespective of weather conditions, and averaged 400 kg/ha of grain. In relative terms the increase was 20-40% in very dry years and 10-20% in favourable years. On average, in the zone 0-30 H (where H is belt height), the increase in grain yield, for belts 12 m high, is 10-12 t/ha of shelterbelt.

809785 C0048-01276 1
Study of the agronomic effects of windbreaks in irrigated areas of the Argentine Middle West. I. Windbreak effects on the growth and development of grapevines.
perimetres irrigues du Centre-Ouest de l'Argentine. I. Effets des brise-vent sur la croissance et le developpement d'une culture type: la vigne.
Simon, J. C.
Station de Bioclimatologie, Avignon, France.
Annales Agronomiques, 1977, 28,1, 75-93
See Abstracts: 00204-C0214
Languages: Fr Summary Languages: en, de, ru
30 ref.
In a trial with grapevine cv. Malbeck grown on the Guyot system with sap-drawers the area protected by a poplar windbreak 10 m high at right angles to dominant winds, mainly from the north, was parallel to it, and 50 m in width. Its effect on the protected grapevines included earlier flowering, fruit setting and veraison, more rapid growth of shoots and fruit, slightly higher grape sugar content and slightly increased yields. The intensification of beneficial effects, compared with those obtained in more temperate climates, is attributed to the protection also given by the windbreak against high accidental winds.

796351 F0039-00287 1
Shelterbelts on peat soils.
Polezashchitnye polosy na torfyano-bolotnykh pochvakh.
Podzharov, V. K.
BelNIILKh, USSR.
Lesnoe Khozyaistvo, 1977, No. 3, 48-50
Languages: Ru
Large areas of peatlands have been drained, cleared of forest vegetation and reclaimed for arable agriculture in Belorussia, but wind erosion, especially in the spring, has proved a serious problem in such areas. As strong winds can blow from any direction in the spring in Belorussia, shelterbelt layouts must give protection from all sides. Permeable belts, 3-5 rows wide, with few or no shrubs, are best. Poplars are among the most suitable species. Recommendations are given on belt layout in relation to road and drainage networks, belt design, choice of species, establishment and tending. Large planting stock is advisable because of the vigorous weed growth, but the best solution is to sow grasses in the belts and harvest as hay. Data are presented on costs and yields.

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764879 S0040-05735 1
Improvement of second rice crop in southern and central Taiwan. 1. Studies on the methods of raising rice yields in ill-drained and west coast areas of Changhua Hsien.
Chang, S. K. ; Hu, C. ; Song, S. ; Hou, F. F. ; Tseng, S. H. ; Hung, C. T.
Taiwan Agriculture Quarterly, 1976, 12,3, 90-97
Languages: Ch Summary Languages: en
In trials in 1975, the average grain yield of 18 rice cultivars was 6.5% higher in well-drained conditions than in poorly-drained conditions in the 1st crop and 3.4% higher in the 2nd crop. Breaking the hard pan increased percolation which tended to accelerate root growth and tillering and decrease plant height. Growth and yield were better with incorporation of compost than with incorporation of straw. Yields were higher with ploughing 18 cm deep with optimum rate of NPK fertilizer than with ploughing 12 or 24 cm deep or with higher rates of fertilizer. Long-grain indica cultivars gave higher yields than japonica cultivars. For the 1st crop optimum transplanting date was 10-20 Mar. with seedlings 45 days old, but for the 2nd crop yield decreased with delay in transplanting and the best date was before 15 July. The most effective windbreak against salt-laden wind was Casuarina equisetifolia and the most effective distance of the wind break from the crop was 5 times the windbreak height. In a field trial irrigation and drainage improvement increased grain yield by 18%.

751142 Q0030-05889 1
Windbreak studies on the Canadian prairie.
Pelton, W. L.
Res. Sta., Agric. Canada, Lethbridge, Alberta, Canada T1J 4B1.
64-68
See Also: 751138 Q0030-05885
Languages: En
9 ref.
Research on the influence of windbreaks on wheat production in W. Canada is reviewed. Windbreaks had little effect on grain yield and new cultural practices controlled soil and snow drift without taking land out of cultivation.

750579 Q0030-05313 1
Improvement of second rice crop in southern and central Taiwan. 1. Studies on the methods of raising rice yields in ill-drained and west coast areas of Changhua Hsien.
Chang, S. K. ; Hu, C. ; Song, S. ; Hou, F. F. ; Tseng, S. H. ; Hung, C. T.
Taiwan Agriculture Quarterly, 1976, 12,3, 90-97
Languages: Ch Summary Languages: en
In trials in 1975, the average grain yield of 18 rice cultivars was 6.5% higher in well-drained conditions than in poorly-drained conditions in the 1st crop and 3.4% higher in

which tended to accelerate root growth and tillering and decrease plant height. Growth and yield were better with incorporation of compost than with incorporation of straw. Yields were higher with ploughing 18 cm deep with optimum rate of NPK fertilizer than with ploughing 12 or 24 cm deep or with higher rates of fertilizer. Long-grain indica cultivars gave higher yields than japonica cultivars. For the 1st crop optimum transplanting date was 10-20 Mar. with seedlings 45 days old, but for the 2nd crop yield decreased with delay in transplanting and the best date was before 15 July. The most effective windbreak against salt-laden wind was Casuarina equisetifolia and the most effective distance of the wind break from the crop was 5 times the windbreak height. In a field trial irrigation and drainage improvement increased grain yield by 18%.

734869 F0038-04074 1
Registration of Hawaiian Giant K8 Leucaena.
Brewbaker, J. L.
Hawaii Univ., Honolulu, USA.
Crop Science, 1975, 15,6, 885-886
Sec Uni Source: Plant Breeding Abstracts 46, 11521.
Languages: En
Derived in Hawaii from seeds of PI 263695, Hawaiian Giant K8 is a self-pollinating variety of L. latisiliqua (L. leucocephala); it combines vegetative vigour with aggressive arboreal growth. It is being grown in the Philippines for charcoal and fuel, and in Hawaii as a fast-growing, deep-rooted, windbreak. When harvested for forage it has produced much higher yields than other common tropical strains.

732603 C0047-07038 1
Temperate tree fruits.
See Also: 732602 C0047-07037
Almonds: Hormone levels in stressed or diseased tissues. Apples: Pollination trials with growth regulators; control of ground cover and effects of herbicides on yield and fruit quality; tree physiology; survey of productivity of British apple orchards; new systems of fruit production; improvement of fruit trees by eliminating virus and mycoplasma infection; effect of latent viruses on tree growth under different nutritional regimes; plant hormone studies; phenolics of fruit plants; effect of growth regulators on tree nutrition; microvegetative propagation; control of fungal diseases by injecting chemicals; eradication of Podosphaera leucotricha with surfactants; phytotoxicity caused by spray materials; low and ultra low volume spraying of intensive orchards; reduction of pesticide losses; pesticide spray deposit and residue analysis; ecology of moth pests of apples; studies on insect pollinators; chemical control of plant diseases; side effects of benomyl; water relations of apple trees; photosynthesis and respiration studies; flavour of Cox's Orange Pippin and variation with CA storage; nutrient mobility studies; metabolism and morphogenesis in cell and tissue cultures; and model of apple tree growth. Pears: Survey of productivity of British pear orchards; effect of latent viruses on tree growth under different nutritional regimes; leaf analysis and nutrition; and control of Stereum purpureum with Trichoderma viride. Plums: Bird damage; chemical control of diseases; biological control of Stereum purpureum with Trichoderma viride; screening for disease resistance; and aroma components of fruit. General: Induction and selection of mutant forms of fruit plants; pollination of pome fruits; growth regulators in fruit production; study on windbreak trees; investigation of methods for use in plant and soil analysis; inorganic N metabolism; metallo-proteins in chloroplasts; amine metabolism in plants; studies on synthesis; analytical methods for pesticide formulations; methodology of controlled environment; basis of pathogenicity; mode of action of fungicides; and biological control of plant pathogens.

724099 F0038-03526 1
Shelterbelts on the virgin lands.
Vekshegonov, V. Ya.
Lesnoe Khozyaistvo, 1976, No. 8, 31-36
Languages: Ru
5 ref.
Reviews the development of grain production in the 'virgin lands' developments in Northern Kazakhstan, and discusses the importance of shelterbelts in increasing the yields of grain in this region. The main species used in the shelterbelts are Populus balsamifera, and Ulmus pumila var. arborea; data are given on growth rates. Grain yields are better with Poplar belts than with Elm belts. The optimum distance between belts of Poplar is 250 m. The economics of shelterbelt establishment

653285 F0038-00242 1
Platanus orientalis.
Mgaloblishvili, S. V. ; Nikolaishvili, R. V.
Subtropicheskie Kul'tury, 1975, No. 5, 79-81
Languages: Ru
BLL
P. orientalis is planted extensively in parks and shelterbelts in Soviet Georgia. Tabulated data are given on its growth rate in a mixed shelterbelt on sandy soils at Poti on the Black Sea coast; it grows slowly in youth, but more rapidly from the age of 10 years onwards, the growth rate reaching a maximum at 25 years. P. orientalis is regarded as a particularly promising shelterbelt species, and efforts are being made to introduce propagation by seed to replace the present practice of vegetative propagation by cuttings.

598566 Q0029-07103 1
Annual windbreaks save moisture.
Rosenberg, N. J. ; Brown, K. W.
Dep. of Agric. Meteorology, Inst. of Agric. and Natural Resources, Nebraska Univ., Lincoln, NE 68583, USA.
Farm, Ranch and Home Quarterly, 1975, 22,3, 11-12
Languages: En
The advantages and disadvantages of annual windbreak crops is discussed. Planted perpendicularly to prevailing winds and at a spacing of 10 X height of the protected crop, windbreaks were most effective. Yields of protected crops increased by an average of 14%. Where maize was used to protect sugar beet, windbreak maize yield was 234 bu/ac compared to a yield of 110 bu/ac in an adjacent pure stand of maize.

144

565557 Q0029-05606 1
Investigations on the possibilities of reducing evapotranspiration in sorghum.
Reddy, M. G.
Coll. of Agric., Dharwar, Karnataka, India.
Publ: Thesis, University of Agricultural Sciences, Bangalore, India.
1974.
Sec Jnl Source: Mysore Journal of Agricultural Sciences 9, 350-351.
Languages: En
In trials with sorghum using different soil moisture conservation practices under dryland conditions, a mulch of Phoenix sylvestris fronds under the protection of a shelterbelt gave the highest increases of 24% in grain yields and 27% in stalk yields and decreased soil moisture consumption by 8%, compared with untreated control plots. Pre-sowing hardening of seeds in water and kinetin solution increased yields by 15 and 3%, respectively. Yields were higher with high plant density than with low plant density, but moisture depletion was lower with low plant density combined with other soil moisture conservation treatments. Application of phenylmercuric acetate (antitranspirant) at 10-4M was toxic to sorghum.

564598 F0037-04508 1
Influence of forest shelterbelts at the Bala State Farm (in central Turkey) on microclimate and agricultural production.
Aydemir, H.
Ormancilik Arastirma Enstitusu Yayinlari, Teknik Bulten Serisi, 1975, No. 68, iv + 58 pp. + 1 map, 2 tab.
Languages: Tr Summary Languages: fr
16 ref.
Describes a field study on the influence of these shelterbelts, already noticed (see FA 20, 1830), which were 3.1-3.4 m high in 1969. Data are tabulated to show the reductions in wind velocity and evaporation at various distances from the shelterbelt, and increases in soil moisture content (by 27-38% compared with an unprotected control site) and in air temperature and humidity. Wheat yields during 1967-73 were 24.9% higher in the protected zone that in the unprotected zone. Graphs and tables have French captions.

564597 F0037-04507 1
Shelterbelt work in the Crimea.
Golod, V. V. ; Pechenkin, M. V. ; Antonyuk, V. G.
Lesnoe Khozyaistvo, 1975, No. 7, 12-14
Languages: Ru
A general survey of experience and the present situation in the establishment and management of shelterbelts in the steppe regions of the Crimea, where ca. 1000 ha of new shelterbelts are planted each year. Typical increases in grain yield weed control in young shelterbelts in various agricultural enterprises in the Crimea.

564422 F0037-04325 1
China uses trees to halt sands.
Wastoby, J. C.
World Wood, 1975, 16,13, 20-22
Languages: En
Reviews the history and development of the Dune Fixation and Shelterbelt Experiment Station since its establishment in 1952 at Chang Ku Tai, Liaoning province, NE China. After several unsuccessful trials, the sands were finally stabilized by the use of four shrub species (Artemisia halodendron, Caragana microphylla, Lespedeza bicolor and Salix flavida). Trials of 34 tree species resulted in the selection of Pinus sylvestris var. mongolica (the preferred species) and P. tabulaeformis for planting on sand dunes, and there is now ample natural regeneration. Since 1964, the station has concentrated on the establishment of shelterbelts each consisting of 7 rows of Populus simonii; as a result, annual cropping is possible, grain yields have doubled, and Pine seed orchards and fruit orchards are being developed (cf. FA 37, 2040).

145

534146 C0046-03160 1
The concentration of sugars and organic acids in grape berries as affected by artificial modifications of the environment.
Die Beeinflussung des Zucker- und Sauregehaltes von Traubenbeeren durch kunstliche Veranderung der Umweltbedingungen.
Klenert, M.
Bundesforschungsanstalt fur Rebenzuchtung, Geilweilerhof, German Federal Republic.
Vitis, 1975, 13,4, 306-318
Languages: De Summary Languages: en
29 ref.
In a 2-year field experiment, meteorological conditions in the vineyard were changed by an artificial windbreak and shading during the period of berry set to fruit maturity. While the first treatment caused no measurable effect, berry growth and ripening were considerably inhibited by shading which reduced the solar radiation to 40-50% of the original values and thus, air, soil and especially plant temperature were comparatively low in the daytime. The amount of sugars in the berries grown under low radiation conditions was decreased. Total soluble solids were 8-14 deg Ochsle below the control at vintage. This was the result of a late beginning of phase IV of berry growth (ripening) and not the consequence of a lower increase of sugar accumulation. The ripening phase was shortened by unfavourable environmental conditions whereas the intensity of sugar accumulation itself was less susceptible to ecological factors. Shading caused a large yield depression in the following year, and the sugar content of the berries at the end of the second experimental period was only 59 g/vine, compared with 209 g in the control. The synthesis of organic acids was retarded in the shaded berries; in accordance with the delayed start of sugar accumulation, the so-called acid maximum was late and lowered. The subsequent decrease of organic acids in the berry proceeded more slowly and at harvest-time grapes grown under shade still had a high acid concentration.

520028 R0018-00957 3
Skin blemish problems of citrus and control with artificial windbreaks. Part III. Economics of wind management.
Freeman, B.
Horticultural Research Station, Narara, New South Wales, Australia.
Australian Citrus News, 1974, November, p.6
Sec Jnl Source: Horticultural Abstracts 45, 10, 7791.
Languages: En
In a trial in an exposed citrus orchard, trees protected by a 45% permeable polythylene mesh windbreak 18 ft high yielded up to 34% more than exposed trees; moreover, fruit quality was greatly improved. Notes are included on the optimum positioning, spacing, height and length of artificial windbreaks and on means of supporting them, with estimates of

508011 00029-00380 1
The response of potatoes to phosphorus and windbreak.
Kratky, B. A. ; Tamimi, Y. N.
Hawaii Agric. Exp. Sta., Beaumont Res. Cent., Hilo, Hawaii, USA.
Hawaii Farm Science, 1974, 21/22,4/1-4, 10-12
Languages: En
The highest tuber yield of potato cv. Pala on a soil high in Ca, Mg and K but with only 4 ppm P, was 191 cwt/ac with P rates of 240 lb/ac broadcast + 240 lb/ac banded 2 in below and 2 in to the side of the seed tuber. Further increases were likely at higher P rates. The presence of a windbreak 15-20 ft high, improved yields from 129 cwt/ac at 81 ft to 153 cwt/ac at 25 feet distance from the row. Soil moisture was significantly higher nearer the windreak, 55.9% at 81 and 67.4% at 25 feet.

507843 00029-00002 1
On "coulisse" fallows.
Antonov, I. S. ; Beketov, A. D.
Sel'skokhozyaistvennyi Institut, Krasnoyarsk, USSR.
Sibirskii Vestnik Sel'skokhozyaistvennoi Nauki, 1975, No.2, 92-94
Languages: Ru Summary Languages: en
In trials in Krasnoyarsk province, S. Siberia, a sunflower 'coulisse' fallow (fallow in which strips of tall windbreaking plants are grown) resulted in accumulation of snow and reduction of wind erosion. In 1967-9 yields of spring wheat grown after the sunflower fallow were increased to 2.34 t grain/ha compared with 1.80 t for wheat grown after bare fallow.

-146

476478 00028-07937 1
Economics of shelterbelt influence on wheat yields in North Dakota.
McMartin, W. ; Frank, A. B. ; Heintz, R. H.
Economic Res. Service, USDA, Fargo, ND 58102, USA.
Journal of Soil and Water Conservation, 1974, 29,2, 87-91
Languages: En
15 ref.
In trials in 1970-2, wheat yields increased with distance away from a single-row shelter belt up to a distance of 5 times the height of the trees (H). Average yields from 14 sites weighted for shelterbelt height were 35 bu/ac for the area up to 13 X H away from the shelter belt and 38 bu for the control area. If the area occupied by the shelterbelt was excluded, the average weighted yield for 1H to 3H from the shelter belt was 38 bu/ac. Yield decreased as shelter-belt height increased.

451345 F0036-06206 1
Pinus pinaster.
Mgaloblishvili, S. V. ; Nikolaishvili, R. V.
Subtropicheskie Kul'tury, 1974, No. 5, 90-92
Languages: Ru
BLL
Gives some data on the growth rate of P. pinaster in pure stands and in a mixed shelterbelt on sandy soils in the Poti region of the Black Sea coast of Soviet Georgia. Most of the plantings are 10-20 years old, but some old park trees are 60-70 years. P. pinaster grows rapidly, especially in youth, and does better in pure stands than in mixtures.

449574 C0045-07791 1
Skin blemish problems of citrus and control with artificial windbreaks. Part II. Artificial windbreaks. Part III. Economics of wind management.
Freeman, B.
Horticultural Research Station, Narara, NSW, Australia.
Australian Citrus News, 1974, 50,November, 4, 6
See Also: 449573
Languages: En
5 ref., 2 pl.
In a trial in an exposed citrus orchard trees protected by a 45% permeable polyethylene mesh windbreak 18 ft high yielded up to 34% more than exposed trees; moreover, fruit quality was greatly improved. Notes are included on the optimum positioning, spacing, height and length of artificial windbreaks and on means of supporting them, with estimates of the costs of establishing natural and artificial windbreaks and of their net return.

Windbreak influence on water relations, growth, and yield of soybeans.
Frank, A. B. ; Harris, D. G. ; Willis, W. O.
Northern Great Plains Research Center, USDA, Mandan, North Dakota 58554, USA.
Crop Science, 1974, 14,5, 761-765
Languages: En
14 ref.
In field trials in 1971 and '72, soyabeans cv. Norman were sown in May in plots measuring 6 X 9 and 9 X 9 m2, respectively, surrounded by a slat fence barrier of about 42% density. In 1971 barrier height was 1.27 m for 57 days after sowing and thereafter to harvest 2.3 m. In 1972 the barrier height was 2.3 m from sowing to harvest. The treatment combination of shelter plus irrigation gave the most favourable plant water status. Under rain-fed conditions where soil water was limiting, plant water status of the sheltered and exposed treatments was similar. DM production, green leaf area and plant height were generally increased under sheltered conditions if soil water was not limiting. Dryland sheltered treatments showed greater early vegetative growth when compared with exposed treatments, but the resulting depletion of soil moisture in sheltered treatments restricted later growth. Both irrigated and rain-fed sheltered plants had a lower leaf density than the exposed plants. Yields were 20.4 hl/ha in irrigated, exposed plots and 24 hl/ha in irrigated, sheltered plots. Under rain-fed conditions yields were 11.8 and 12.8 hl/ha for exposed and sheltered plots, respectively.

419124 F0036-04744 1
Improving the effectiveness of shelterbelts.
Kalashnikov, A. F.
Lesnoe Khozyaistvo, 1974, No. 10, 40-44
Languages: Ru
4 ref.
Discusses the efficiency (KPD) of shelterbelts, expressed as the % area of a field bordered by shelterbelts that actually benefits from the influence of the belts. KPD changes with the age (height) of the belts and with the belt structure, and is related to the soil type. The latest instructions in the USSR are that the belt spacings (in a grid system) should not exceed 600 X 2000 m (i.e. a field size of 120 ha) on grey forest soils and on podzolized and leached chernozems; 500 X 2000 m (100 ha) on typical and ordinary chernozems; 400 X 2000 m (80 ha) on southern chernozems; 350 X 2000 m (70 ha) on dark-chestnut and chestnut soils; and 250 X 2000 m (50 ha) on light-chestnut soils. Various examples are discussed of the efficiency of shelterbelt systems and their effect on grain yields.

147

417120 C0045-05747 1
Experimental modification of the meteorological conditions within a grape canopy and their effects on berry growth.
Kunstliche Veranderung der meteorologischen Verhaltnisse im Rebbestand und ihre Auswirkungen auf das Grossenwachstum der Traubenbeeren.
Klenert, M.
Bundesforschungsanstalt fur Rebenzuchtung Geilweilherhof, German Federal Republic.
Vitis, 1974, 13,1, 8-22
Languages: De Summary Languages: en
40 ref.
In a 2-year field experiment microclimatic changes were induced by artificial shading or a windbreak during the period between flowering and harvest. The effects of these treatments on the meteorological conditions in the vineyard and on the growth of the berries were investigated. In spite of considerable dimunition in the wind speed the windbreak had little effect: the temperature regime within the canopy was unchanged and no effects on berry growth were observed. However, solar radiation (0.3-2.5 mu m) and light intensity were reduced by shading to such an extent that berry growth was considerably impaired. The solar radiation, measured on a clear summer day, was decreased from 410 cal/cm2 to 160 cal/cm2, and for the 100-day period the shaded vines received about 13 kcal/cm2 as against 29 kcal/cm2 in the control. Consequently plant temperature, in particular, diminished, whereas air temperature within the canopy was only slightly lowered. The berries were smaller, resulting in a yield loss of about one-third.

362185 C0045-01305 1
Passion fruit growing in Kenya.
La culture de la grenadille au Kenya.
Aubert, B.
Institut Francais de Recherches Fruitieres Outre-Mer, Saint Denis, Reunion.
Fruits, 1974, 29,4, 323-328
Languages: Fr Summary Languages: en, de, es, ru
7 ref., 9 pl., 1 fig., 1 map
The purple variety of passion fruit (P. edulis) is intensively grown in some parts of Kenya, either in vegetable holdings, where it serves additionally as a windbreak, or in young macadamia orchards. The plants are spaced at 7 or 8 m, the leaders are trained along a single overhead wire 2 m from the ground and fruiting branches are allowed to hang down freely. Regular weekly pruning is necessary to curb excessive growth, and branches which have finished fruiting are also cut back. Yields are of the order of 30-40 t/ha, 7 or 8 times greater than from unpruned plants.

McMartin, W. ; Frank, A. B. ; Heintz, R. H.
Journal of Soil and Water Conservation, 1974, 29,2, 87-91
Languages: En
15 ref.
Reports results of 3-year study of 14 single-row shelterbelts of Ulmus pumila and concludes that although these may prevent soil erosion, trap snow, provide wildlife habitat, etc., wheat yields were not increased.

303718 C0044-10005 1
Effect of windbreaks on tree vigour and yield in sweet orange.
Jawanda, J. S. ; Mehrotra, N. K. ; Singh, R.
Regional Fruit Research Station, Abohar, India.
Punjab Horticultural Journal, 1973, 13,1, 21-24
Languages: En
5 ref.
Windbreak trees 15-17 m in height planted in a single row along 3 sides of an orchard of Blood Red oranges did not affect the growth of orange trees in the rows adjacent to the windbreaks, but their yields were significantly reduced, probably by the shade.

303717 C0044-10004 1
How artificial windbreaks help citrus growers in Australia.
Freeman, B.
Horticultural Research Station, Narara, NSW, Australia.
Citrus and Sub-Tropical Fruit Journal, 1974, No. 483, 4-6, 8
Languages: En
5 ref., 2 pl., 1 fig.
In a trial in an exposed orchard, trees protected by a polythene mesh windbreak 5.5 m high yielded up to 26% more than exposed trees, and the average yield increase for the protected block was 20%. This was associated with increases in both fruit size and number; moreover, fruit quality was greatly enhanced. Details are included of the positioning and construction of the artificial windbreaks, and of the estimated costs and returns.

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304974 F0035-07589 1

296664 F0035-06854 1
A comparative study on the rate of growth of Casuarina spp. and Eucalyptus camaldulensis and its yield on sandy soil irrigated by sewage water at Gabal el Asfar.
Imam, M. el S. ; Heikal, I. A.
Agricultural Research Review, Egypt, 1972, 50,4, 127-137
Languages: En
13 ref. NLL
Reviews literature on growing conditions and performance of the species, and reports a study of selected 10- and 15-year-old trees planted individually, in rows to act as a windbreak, or in plots within a 500-acre afforestation area. Data are tabulated for height growth, girth and weight (t/tree); they show that the species are suitable for planting on sandy soils, if irrigated by sewage water, because of their tolerance to salt in the soil and their rapid growth. Survival, vigour and yield of E. camaldulensis at age 15 years were generally better than for Casuarina spp., but Casuarina spp. are more suitable for planting in windbreaks.

226507 F0035-01569 1
Effectiveness of shelterbelts in the south Ukraine.
Miloserdov, N. M. ; Paladiichuk, A. F. ; Antonyuk, V. G.
Lesnoe Khozyaistvo, 1973, No. 7, 32-36
Languages: Ru
A survey is made of the effectiveness of shelterbelts in assisting the survival and improving the yields of winter grain crops in 1972, after unusually adverse weather in 1971/72 (autumn drought, low temperatures and dust storms in winter and spring). Survival increased with increasing density of shelterbelts (expressed in terms of area of belts per 100 ha of field). Yields were affected by the distance from the belt, and also by the design of the belts, i.e. dense, semi-permeable, and permeable. Results indicated that the average additional revenue from increased yields attributable to the influence of the shelterbelts was 468 roubles per ha of shelterbelt.

066716 C0043-01474 1
Wind and its effects on citrus trees at Loxton, South Australia.
Campbell, M. M. ; Mills, G. A.
Department of Agriculture, Loxton.
Experimental Record, 1972, No.7, 20-35
See Also: 066715
Languages: En
12 ref., 3 pl.
Observations were made in mature citrus orchards, including orange. Tabulated data are included on the degree of leaf damage caused by wind and the corresponding leaf Cl content in exposed and protected branches, the percentages of protected halves of a row of trees forming a windbreak and the mean percentage surface area of fruits showing damage at intervals throughout the year.

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296664 F0035-06854 1
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12 ref., 3 pl.
Observations were made in mature citrus orchards, including orange. Tabulated data are included on the degree of leaf damage caused by wind and the corresponding leaf Cl content in exposed and protected branches, the percentages of wind-damaged fruits on exposed and protected branches and trees, the yield and quality of the fruits on exposed and protected halves of a row of trees forming a windbreak and the mean percentage surface area of fruits showing damage at intervals throughout the year.

SECTION IV

SELECTED ANNOTATED BIBLOGRAPHY

FROM

Windbreaks for Conservation

April 1984

Publication No. WB 84-01

California Department of Conservation
Division of Land Resource Protection
1516 9th Street, Rm. 400
Sacramento, CA 95814, USA

151

Anonymous, 1968. "Soybean yields increase with windbreaks." Soybean Digest 28(7): 17.

Yields of soybeans were increased by 20 to 25 percent in trials during four years in Texas. Maize was sown in double rows for every 12 rows of soybean. This gave a ratio of 10:1 for the distance between windbreaks to the effective windbreak height (height of maize less height of soybean).

Anonymous, 1974. "Wheat wind stripping protects cotton in Arkansas." Cotton Growing Review 52: 243.

Many farmers in the sandy soil areas of Arkansas "wind strip" their fields to protect cotton seedlings from blowing sand. Wind strips are narrow lanes of small-grain cover crop left at intervals across the field to serve as windbreaks until the cotton plants are several inches high.

Anonymous, 1981. "Wind's effect on grapes studied at U.C. Davis." California Farmer 257(4): 32.

The effects of wind on grapes are being studied. Wind shields have been erected to control fruit scarring. The major objectives of this experiment are to find out at what speed winds cause problems, and to what extent they cause a disadvantage in the life processes of plants.

Anonymous, 1982. "Tips for feeding your beef cows this winter." Prairie Farmer.

According to the article, energy (and therefore food) requirements for healthy cows increase 13 percent for every 10-degree drop in wind chill temperatures below 30 degrees. Cows in poor condition require 30 percent more energy for every 10-degree drop. This particularly applies to thin cows with poor hides.

Bagley, W.T., 1964. "Response of tomatoes and beans to windbreak shelters." Journal of Soil and Water Conservation 19(2): 71-73.

In central Nebraska, changes in microclimates caused by a 7-foot high wood-slat windbreak resulted in earlier germination, faster vegetative growth, earlier ripening fruit and 16 to 40 percent increases in the yield of tomatoes and snap beans.

157

Bagley, W.T. and Gowan, F.A., 1960. "Growth and fruiting of tomatoes and snap beans in the shelter area of a windbreak." Paper No. 1040, Journal Series, Nebraska Agricultural Experiment Station.

In order to determine the effects of windbreak protection on tomatoes and snap beans, two sets of seven-foot snowfence windbreaks were erected in Buffalo County, Nebraska. The windbreaks were oriented east-west and were 246 feet long with 42 feet between each pair. One windbreak pair was located 240 feet east of the other pair. Porosity was estimated at 57 percent of total screened area. Primary wind direction was from the south, with some occasional winds from the north. Tomatoes and snap beans planted within the sheltered areas showed overall yield increases of 16 percent and 37 percent, respectively, over unprotected yields. Relative humidity was also higher in the sheltered zones.

X Bennett, C., 1980. "Cold diverts cow energy from meat to heat." California Cattlemen pp. 28.

First reports of a three-year University of California study in Modoc County show that cold weather is causing a loss of money to cattlemen in northeastern California. The study evaluated the difference in dollar value between calves kept in unsheltered lots or fields during winter and those protected by windbreaks. The cold stress in the unprotected calves was significant. The sheltered animals yielded a profit of over $40 per head higher than those unsheltered.

Blanchard, V.F., 1934. "Depressing effect of wind on growth and yield of citrus trees." California Citrograph 19(8): 206.

Wind depresses the growth and fruit yield of citrus trees. The author states that protected trees are 1/3 larger and produce 286 field boxes of fruit compared to 43.6 boxes from unprotected trees.

Brandle, J.R., Johnson, F.F. and Dearmont, D.D., 1981. "Field Windbreak Economics" Paper No. 6966. Journal Series, Nebraska Agricultural Experiment Station.

There seem little doubt that plants benefit from reduced wind speeds. But is there enough compensation for the land that the trees occupy? According to this paper the

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total present value of a windbreak investment over a 50-year life is $57,277.00. Assuming an establishment cost during the first three years of $1,247.00, the net present value is $56,030.00 or $1,200.00 a year. Pay-back would begin around the 12th year, with positive revenue beginning to flow around year nine. The authors believe this justifies using a windbreak.

Brown, K.W. and Rosenberg, N.J., 1975. "Annual windbreaks boost yields." Crops and Soil 27(7): 8-11.

An annual windbreak instead of a tree windbreak could be more beneficial in some cases. They do not provide year round protection but they are low in cost, require a minimal amount of land, provide almost immediate protection for crops, allow flexibility from year to year, and can also be harvested for additional income. The author states that in a dry year, a 50 percent porosity windbreak of corn increased a sugar beet field yield by 14 percent, but a range of 10 to 50 percent in yield increases on other fields was noticed.

Cardwell, G.A., 1936. "Windbreaks protect early vegetables in South." Market Growers Journal 58(7): 182-185.

Along the coast of Virginia and the Carolinas, a natural windbreak is formed by clearing parts of the forest. The author interviews six agricultural experts to get their views on windbreaks. All agree that the benefits from a windbreak outweigh the costs.

Cook, D.I. and Van Haverbeke, D.F., 1976. "Residential traffic noise control using tree-shrub-barrier combinations." Great Plains Agricultural Council Publication 78: 112-116.

Trees, shrubs and solid barriers will act as an effective shield in suburban areas from noise of normal passenger car traffic. A noise level reduction of nearly 2/3 is possible with dense plantings of shrubs combined with taller trees. Generally, barriers placed close to a noise source are more effective than one placed midway.

Cross, J.M., 1974. "Windbreaks for beefsteaks." Soil Conservation 29(9):18-19.

Windbreaks can be used to keep cattle warmer in the winter. If cattle are warmer, they will eat more and gain weight. They burn up less feed trying to keep warm.

Cunningham, R.A., 1976. "Genetic potential for better trees." Great Plains Agricultural Council Publication 78: 160-162.

The forestry service can increase genetic potential of trees in a short period of time and at little cost by following five steps explained in this article: (1) labeling the seed source; (2) using local seed sources (3) using proven seed sources; (4) selecting plus-trees of plus-stands, and (5) establishing seed production areas.

Dice, J.R., 1940. "The influence of stable temperature on production and feed requirements of dairy cows." Journal of Dairy Science 23(1): 61-69.

Data presented in this article shows that dairy cows receiving an adequate ration of food, having shelter from the wind, snow or rain, and capable of withstanding exposure to cold temperatures will produce practically the same in a cold stable as they will in temperatures of about 50°F.

Dice, J.R., 1942. "The ability of yearling heifers to withstand cold temperatures." Journal of Dairy Science 25(8): 678-679.

A program concluded that dairy cows tend to put on more weight and produce more milk in an area which is protected than in an area which is open.

Durzan, D.J., 1982. "Improving woody crops." California Agriculture 38(8): 34.

Cloning wood species to be less dependent on fertilizers, more responsive to cultural practices and able to grow in harsh climates is now possible. The technique used is cell suspensions and researchers are now looking into the application of recombinant DNA technologies to protoplasts. This would produce "super" trees that could be used for windbreaks in harsh environments.

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Frank, A.B., Harris, D.G., and Willis, W.O., 1977. "Growth and yield of spring wheat as influenced by shelter and soil water." Agronomy Journal 69(6): 903-906.

In 1973-1974 spring wheat was grown with and without slat-fence enclosures and either with or without irrigation. The combination of shelter with irrigation was more favorable than with irrigation alone. Grain yields increased from 2.94 ton/ha with irrigation to 3.58 ton/ha for shelter with irrigation. Dryland wheat was 1.36 ton/ha for exposed lots to 1.58 ton/ha for sheltered crops.

Hall, L., 1977. "Do plants shiver in the north wind?" Organic Gardening and Farming 24(10): 92-94.

The author disagrees with an article of the American Fruit Growers Exchange (November 1976) stating that wind chill doesn't affect trees. This Vermont nurseryman knows from first hand experience that windbreak protection will let plants grow at a faster rate than non-shelter plants.

Hart, S.A., Wilson, W.O., and Woodard, A.E., 1957. "The value of windbreaks for winter protection of chickens in California cage houses." Poultry Science 36(3): 662-669.

At U.C. Davis, experiments on the effects of wind velocity and egg production were conducted. Over three successive winters it was found that: (1) egg production increased with the help of a windbreak; (2) correlation of feed consumption and egg weight to wind protection by windbreaks was not statistically significant; (3) layers were less likely to stop production when sheltered by windbreaks; and (4) birds out of production were more likely to return into production when sheltered by windbreaks.

Johnson, H.D., 1965. "Response of animals to heat." Meteorological Monographs 6(28): 109-121.

Animals are directly affected by temperature, wind, radiation, barometric pressure and humidity. They are indirectly affected by climate changes caused by the plants and soils around them. This article explains the different types of shelters that can be used to help increase productivity.

Konstantinov, A.R. and Struzer, L.R., 1965. Shelterbelts and Crop Yields. Lenigrad: Gidrometeorologicheskor Izdalel stvo. Translated from Russian by the Israel Program for Scientific Translation. pp. iii+138.

Shelterbelts favorably affect the conditions of growth of field crops by reducing the wind speed and increasing soil moisture content. This book explains technical research of the influence of shelterbelts on the hydrometeorological factors of crop production, crop productivity and forecasting variations of evaporation and the water balance of large territories due to the action of shelterbelts.

Kosco, B.H. and Bartholome, J.W., 1978. "Grazing mixed conifer forests." California Agriculture 32(5): 5-7.

Grazing on mixed conifer forests has some benefits. It can reduce fire hazard and enhance tree growth by reducing understory vegetation. Also, it can protect animals from the bad weather. Much more research needs to be done on the relationships of grazing, tree reproduction and timber production.

Lee, B.W., 1976. "The Quince." Leaflet 2490, Division of Agricultural Science, U.C. Davis.

Quince, Cydonia oblonga, is explained along with certain requirements this plant needs to grow. The leaflet explains how to care for them and how to utilize the quince for hedges.

Lombard, T.A., 1950. "Eucalyptus windbreaks vs lemon production." California Citrograph 35(7): 301.

There is a considerable justification for removing eucalyptus windbreaks around lemon orchards. The author states that production is lower because roots and limbs of the eucalyptus interfere with the orchards and frost develops in areas that are protected by windbreaks. Only in areas of extreme wind is a windbreak necessary.

Lundemo, J.R., 1921. "Value of effective windbreak to citrus orchards." California Citrograph 6(3): 76,91.

A citrus orchard in southern California was protected from Santa Ana wind by a blue gum eucalyptus windbreak. The managers of the orchard had kept meteorological records since the day the windbreak was planted. With the trees reaching the desired height, wind speeds were reduced by 50 percent thus minimizing mechanical damage of the fruit (such as bruising and falling off trees). Also, the windbreak tended to stabilize the daily temperature of the orchard. The farmer rips the roots every year so that the first row of trees are not damaged. The author is supportive of windbreaks and believes that they are beneficial to citrus growers.

Lynch, J.J., 1980. "Changes in pasture and animal production resulting from the use of windbreaks." Australian Journal of Agriculture Resources 31(5).

The effects of windbreaks on sheep production were studied for five years.. With a density of 30 sheep per hectare, there was an increase in plant and animal productivity from the sheltered paddocks during the last two years. Results indicate that shelter may have an important place in increasing pasture and animal production.

Lynch, J.J., and Alexander, G., 1976. "The effects of gramineous windbreaks on behavior and lamb mortality among shorn and unshorn merino sheep during lambing." Applied Animal Ethology 2(4): 305-325.

Strips of tall grass (Phalaris hybrid) one foot thick and two feet high were established at 20-foot intervals in small paddocks to test the effects of shelters on merino sheep during lambing. At night, 70 percent or more shorn ewes were found within two feet of the shelters, 40 percent during the day. Unshorn ewes also stayed within two feet of the shelter but to a lesser degree and much less regularly than the shorn ewes. Lambing sites were also concentrated within two feet of the shelter. The incorporation of shelter strips of tall grass into a pasture offers a simple way of providing shelters for grazing animals in areas susceptible to bad weather.

Marshall, J.K., 1974. "Effects of shelter on the growth of turnips and sugar beets." Journal of Applied Ecology 11(1): 327-345.

Sugar beets and turnips were grown at two sites in England and protected by a north-south screen with 50 percent permeability. Plants from sheltered crops had greater leaf areas but by the end of the growing season there were no significant yield differences. Potential evapotranspiration was lower in the sheltered area.

McLeod, J.W., 1964. "Planting for Christmas Trees." Publication No. 1083, Canadian Department of Forestry.

Christmas tree production is becoming an additional income to some farmers. This booklet is designed to assist those who are interested in growing them. General site requirements and principles involved in planting are explained. Requirements and characteristics of common Christmas tree species such as Douglas fir, Scots pine, red pine, white spruce and Norway spruce are discussed.

McMartin, W., French, A.B., and Heintz, R.H., 1974. "Economics of shelterbelt's influence on wheat yields in North Dakota." Journal of Soil and Water Conservation 29(2): 87-91.

Single row shelterbelts that protect wheat produce low yields at one H and two H compared to areas of no influence. Farther away, yields increase until they reach levels above the no-influence area. The net result for the entire field was a modest reduction in overall wheat production. Results of this study planting cannot justify windbreaks on the basis of increases in wheat production. Other benefits such as snow catch, prevention of soil erosion and aesthetic values must be considered, however.

Metcalf, W., 1936. "The influence of windbreaks in protecting citrus orchards." Journal of Forestry 34(6).

Winds of high velocities cause fruit scarring and, in unprotected orchards, loss of fruit from the trees. Examples are given demonstrating how wind damage has resulted in reduced citrus yields and economic loss. Windbreaks are economically

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feasible for high value citrus orchards, but must be of adequate height to protect the entire orchard. Many examples of specific situations in California are given.

Morrison, S.R., Pierce, C., and Dunbar, J., 1979. "Windbreak protection for wintering calves." California Cattleman.

Northeastern California cattle are often wintered in unsheltered areas. Because of the high price of feed, reductions in growth or increases in feed consumption due to cold stress can be economically unattractive. Wind chill as it effects temperature stress is particularly significant. Their study showed greater weight gain with less feed intake in the wind sheltered sections. They recommend weighing that information against costs of hay and shelters to determine the economic feasibility of windbreaks.

Ogbuehi, S.N. and Brandle, J.R., 1981. "Influence of windbreak-shelter on light interception, stomatal conductance, and CO_2 - exchange rate of soybeans Glycine max (Linnaeus Merrill)." Transactions of the Nebraska Academy of Sciences. 9: 49-53.

Sheltered soybean plants exhibited greater CO_2 exchange rates and stomatal conductance than those in an unsheltered test area during a field study. As a result, it was concluded that soybean production should be improved by windbreaks.

Pelton, W.L., 1967. "The effect of a windbreak on wind travel, evaporation and wheat yield" Canadian Journal of Plant Science 47: 209-214.

A windbreak was erected in a wheat field during the growing seasons of 1960 through 1964. The effects of this barrier on wind travel, evaporation and wheat yield were measured. The windbreak reduced wind travel by 15 percent to 49 percent and led to reductions of 12 percent to 23 percent in evaporation. Yields within the sheltered area ranged from 24 percent to 43 percent above control yields. Maximum grain production was obtained in the area of maximum wind and evaporation reduction. However, yields in general were extremely variable throughout the test area during individual years and from year to year. The author suggests that the wide variations in yield are caused by the effects of other environmental factors that were not studied.

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Pelton, W.L., 1976. "Windbreak studies on the Canadian prairie." Research Station Canada: 1-4.

Research on the influence of windbreaks on wheat production in West Canada is reviewed. Windbreaks had little effect on grain yield, and cultural practices controlled soil and snow drift without taking land out of cultivation.

Radke, J.K. and Hagstrom, R.T., 1973. "Plant water measurements on soybeans sheltered by temporary corn windbreaks." Crop Science 13(5): 543-548.

In field trials in 1969, 14 rows of soybeans were grown between double rows of maize. Wind speed and potential evaporation were significantly reduced in seven to eight soybean rows to the lee of the windbreak. Yields between windbreaks were four to five percent higher than those from open plots, and a 15 percent increase was obtained where hail damaged the crop.

Read, R.A., 1956. "The effects of livestock concentration on surface soil porosity within shelterbelts." Research Notes 22, Rocky Mountain Forest and Range Experiment Station, U.S. Department of Agriculture, pp. 1-4

The effects of livestock browsing and trampling can be detrimental to a windbreak. Browsing will cause defoliation of undergrowth. This condition tends to decrease windbreak efficiency. Trampling is less observed but is likely to affect tree growth and vigor over a period of years by creating unfavorable site conditions. Tree roots are frequently exposed and injured by trampling. The concentration of livestock use in shelterbelts results in soil compaction.

Rediske, J.H., 1976. "Propagation techniques on the horizon." Great Plains Agricultural Council Publication 78: 144-146.

The development of tissue culture technology and its application will make mass vegetative propagation in the forest industry possible. Application of this would produce specialized windbreak trees.

Robbins, C., 1976. "Economics of windbreaks and our cattle industry." Great Plains Agricultural Council Publication 78: 107-108.

Farmstead windbreaks are being used for livestock operations. Exact financial figures derived from the benefit of windbreaks are hard to calculate, but the beneficial effects of reduced weight loss and cattle deaths in a cold winter can readily be seen.

Shea, P., 1969. "Windbreak fences yield comfort for cows and convenience for dairymen." Dairy Herd Management 6(8): 20-21.

A good fence will provide protection from the wind in cattle yards. The article also explains what type of fence to use, and suggests a good design for a cattle area.

Sheikh, M.I., and Shima, A.M., 1976. "Effects of windbreaks on the yield of wheat crops." Pakistan Journal of Forestry 26(1): 38-47.

Effects of various tree-row windbreaks on wheat grain yields were investigated at six sites in 1975. Yields were relatively low near the trees, especially when they were orientated north-south. Low yields were attributed to shading but it was suggested that eventual timber sales would offset the yield loss.

Smith, B.D. and Lewis, T., 1972. "The effects of windbreaks on the blossom-visiting fauna of an apple orchard and on yield." Annals of Applied Biology 72(3): 229-239.

A windbreak of coir netting was set up in apple orchards during flowering periods in 1969 and 1970 to increase the number of insect pollinators present. The sheltered area was found to contain more species of insects than the unsheltered area. Increases in final fruit set of approximately 30 percent in 1969 and 20 percent in 1970 were measured. A possible explanation is the increased activity of honeybees. Windbreaks were not present during growth and flower bud development.

Stoeckeler, J.H., 1963. "Shelterbelts and their effects on crop yields in the Great Plains." Journal of Soil and Water Conservation 18(4): 139-144.

The net increase in grain yields of east-west shelterbelts were 87 percent for maize and 67 percent for other cereals. Shelterbelts were of great benefit because of a greater amount of soil moisture.

Ventulett, D.P., 1955. "Windbreak strips protect watermelons." Soil Conservation 20(12): 274-275.

In Florida, farmers are growing blue liysine and small grain to help their watermelon vines. These windbreak strips, coupled with the use of sod in the crop rotation system, have reduced sand blowing and improved the soil in the area.

Wahlberg, H.E., 1941. "Windbreaks for orchard protection." California Citrograph 26(12): 359, 372-373.

The need for higher yields per acre and better quality of fruit prompted the use of windbreaks in the citrus section of southern California. This article explains how to plant eucalyptus and Arizona cypress and how to maintain them after establishment.

Young, F.D., 1927. "Windbreaks effectiveness in southern California orchards." California Citrograph 12(12): 424.

The effects of wind on an orange orchard are studied. The orchard was protected by blue gum eucalyptus. For two seasons, wind velocities behind the windbreak and in a control area were monitored. It was noted that a 50 percent decrease occurred at 15H behind the windbreak. Stations in the open had a maximum average of 22 mph while behind the windbreak it was 9 mph.

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SECTION VI

INSTITUTE OF CURRENT WORLD AFFAIRS

PJW-15
(No Longer) Blowin' in the Wind

Dakar, Senegal
28 February 1985

Mr. Peter Bird Martin
Executive Director
Institute of Current World Affairs
4 West Wheelock Street
Hanover, NH 03755 USA

Dear Peter,

In mid-February the Harmattan winds off the Sahara Desert are still blowing strong in Niger. In Niamey the air is full of brown dust, but farther east, hard driving winds blow gritty sand through the Majjia Valley. Quite literally the desert seems to be on the move, engulfing the countryside. The true desert is farther north, but the sparse Sahelian vegetation and omnipresent sand suggest a closer presence. Combatting desertification is a high priority of the Nigerien government. Increasingly emphasis is being given to forestry and soil conservation efforts, particularly since last year's national conference on desertification held at Maradi.

"Majjia" is a Hausa word for "valley". The Majjia Valley is located in southern central Niger (see map on page 2), over 500 kilometers (300 miles) east of Niamey. An ancient sea bed, the Majjia is a fertile agricultural valley. From the plateau to the north of the valley, the Majjia looks bleak and desolate, with few trees in evidence. The descent into the valley from Bouza is steep and rocky, passable only to four-wheel-drive vehicles, donkeys, and camels. There is no permanent river flowing through the valley: the floodplain has water only after the rains. Yet the valley is not as difficult as it initially appears. An estimated 33,000 people live in the Majjia, comprising twenty-seven villages. The area's residents make their living from growing crops, such as millet, sorghum, and a little cotton, and raising livestock, such as goats, sheep, donkeys, and camels.

The strong winds that blow through the Majjia threaten the villagers' livelihood. During the long dry season, from November to May, little vegetation covers the ground: the Harmattan blows almost incessantly, carrying away valuable topsoil. During the rainy agricultural months, the wind continues to blow, drying out young sorghum and millet plants.

Among development foresters, the Majjia Valley has become quite celebrated as a successful social, or community, forestry project. For the past ten years, CARE International, a private

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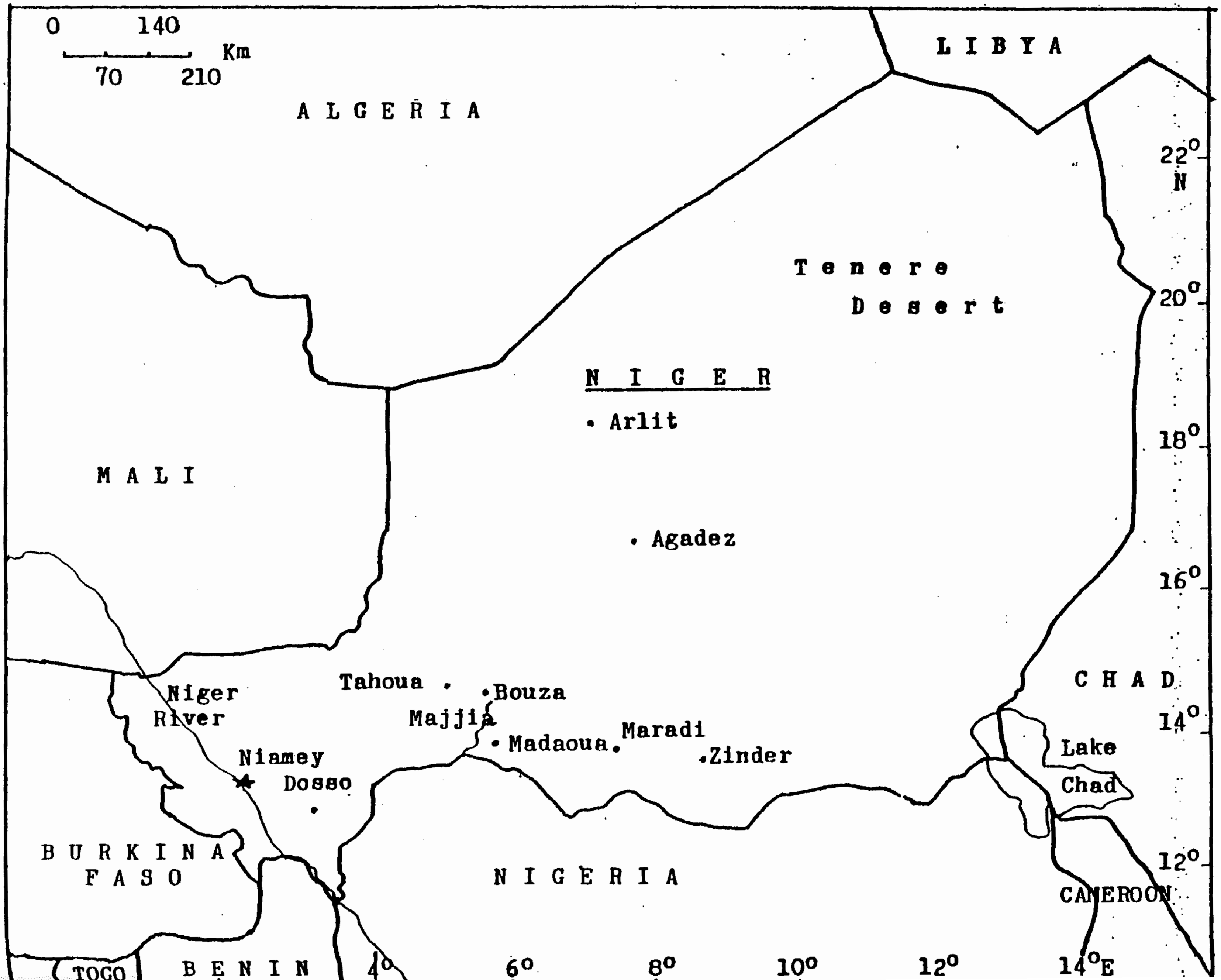
MAP OF NIGER

(Adapted from: Atlas du Niger, Editions Jeune Afrique, Paris, 1980 pp. 6-7.)



voluntary development organization, has promoted tree planting in windbreaks[1] in the valley. The project was designed to protect and conserve soil, protect agricultural production, and to produce wood for use as fuel and poles.

The windbreaks consist of double rows of trees, planted 4 meters (13 ft.) apart, with 100 m (330 ft.) between the double rows. Many windbreaks exceed 1 kilometer (0.6 mi.) in length: some are perhaps 2 km long. Since 1975, 314.7 km (195.6 mi.) of windbreaks have been planted, using 121,600 trees, and protecting an agricultural area of 3147 hectares (7776 acres). An average of fourteen to sixteen windbreak lines have been planted each year.[2]

The first windbreaks were planted in the northern part of the valley, near the three villages of Garadoumé. Subsequent lines have been planted extending southward. More recently, windbreaks have been put in near Taboé and have been extended northward. Within a couple of years, the two sets of lines will meet and the valley will be protected for a distance of 20 km (12 mi.). The size of the project is a bit difficult to conceptualize in the abstract. The visual impact of seeing the project on the ground, however, is quite impressive: the rows of trees go on and on. What is particularly significant is realizing the numbers of people that have been involved in planting all of these trees, both in terms of the laborers and the landowners.

The project began when a Nigerien forester, Daouda Adamou, and a Peace Corps forester, Don Atkinson-Adams, approached CARE in 1974 for financing. Daouda had been the forester for the Bouza Arrondisement[3] for several years. Having excellent rapport with the villagers, Daouda had already persuaded many local residents to plant individual woodlots and trees. Bouza, Daouda's base as well as his home town, has a marked abundance of trees lining the streets and shading a town park.

The valley's residents were themselves interested in planting the windbreaks, as they were concerned about the wind erosion in the valley. They had great confidence in Daouda and had already experienced the success of the woodlots, in producing wood needed locally for poles.

The project was set up with CARE providing the financing, and the villagers the labor and land. CARE established three small nurseries to produce tree seedlings, which involved digging wells, purchasing metal fencing, seeds, fertilizer, and other supplies, and paying the salaries of nursery workers. CARE has also provided transport for the seedlings, technical assistance (in conjunction with Peace Corps and the Nigerien Service of Forests and Fauna), and paid guardians to protect the trees -- for the first three years after planting -- from livestock grazing.

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The project began towards the end of the last major Sahelian drought. Initially some workers were given food for their labor, through a Food-for-Work program. The majority, however, has been voluntary labor. Young men's groups, called Samaria, have planted the trees. The work involves two phases: the holes for the trees are dug late in the dry season, and the trees are planted after the first major rain. The work parties generally have large turnouts and the air of a festival. Women sometimes cook for the work parties. Often a local griot, or hereditary musician, will beat his drum to encourage the workers.

Although the villagers wanted to establish the windbreaks, many were initially reluctant to give up some of their own land to the project. To be effective, however, the project needed to cover a lot of land and required coordination among adjacent landowners. As individual fields in the valley are small in size, many landowners were involved. The project was fairly arbitrary: trees were planted in straight lines, in parallel double-rows, perpendicular to the wind, for a minimum distance of at least 200 m (660 ft.). Consequently, it was not possible to curve or wiggle the windbreak lines around reluctant landowners.

The fact that the project has worked is testimony to the charisma and hard work of Daouda and his colleagues, in convincing villagers and local government officials of the validity of the project. The support of local authorities was particularly crucial in winning over the valley's population. Daouda himself has said that the fact that he was always accompanied on his field trips by the Sous-Prefet was a significant factor. The Sous-Prefet's presence impressed both villagers and other government officials of the project's importance.[4]

As the project has progressed, villagers have come to believe that the initial layout of the lines was wise. Furthermore, they are convinced that the windbreaks are improving their agricultural productivity. Nearby residents have expressed interest in starting their own planting programs. CARE has recently begun financing programs in five nearby areas.

Development workers have also grown increasingly interested in the project, in understanding both the project's actual impacts and the possibilities for replication elsewhere. A small study undertaken by a Dutch graduate student in 1980 suggested that the windbreaks had increased agricultural productivity by 23 percent.[5] This year a major evaluation study, financed by CARE and the U. S. Agency for International Development, is underway. The study began in March 1984 and is scheduled to be completed by fall 1985.

According to Dr. Steven Dennison, the forest economist heading up the evaluation, the study has four purposes. The evaluation is being undertaken to assess whether the project objectives have been met, whether the project is integrated into the local

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communities and to what degree it is accepted, whether there are costs and benefits unforeseen in the original project design that warrant evaluation, and how the project may be improved. To answer these questions requires a sociological survey, a technical study examining the regeneration rates of trees to three different types of cuts, soil and meterological conditions, and the impact of the windbreaks on crop production, and an economic and financial analysis.

The sociological survey, supervised by James Delehanty, Marilyn Hoskins, and James Thomson, was conducted between May and July 1984. Six local Hausa-speaking interviewers, three women and three men, questioned 211 local women and 209 local men on the project's desirability and on other agroforestry practices. In-depth interviews were conducted with a smaller number of informants. As much livestock in the valley is raised by women, they were found to have suffered disproportionately from the project, as their animals could not graze in the project areas.

The social researchers found that most local residents do not believe that they own the trees -- most think that the trees belong to the local forester or to the government. As wood production begins to be managed and exploited from the windbreaks, the distribution of benefits will need to be well worked out.

This year's experimental cut provided the first step in that direction. Under the supervision of CARE's foresters, 205 trees were cut to assess the impacts of various cutting methods -- coppicing, pollarding, and partial pollarding[6] -- on regeneration. The trees were cut just before the rainy season, the optimal time to get resprouting.

The wood was cut by village men from Garadoumé. When the wood was cut, the Sous-Prefet announced that the wood belonged to the villagers. Those doing the work were given the wood to distribute as they saw fit. Some wood was given to the village chiefs, the rest distributed among the woodcutters themselves. Although obtaining firewood is women's work here, the women did not participate in the firewood distribution. Project staff are hoping that the free distribution of wood will convince villagers that the trees do belong to them, and not to the project, forester, or government. Project staff are also hoping to enhance women's participation in future project activities.

Despite the villagers' interest in the project, it seems unlikely that the project could be carried out by local farmers themselves, if CARE financing ends. The project has been costly, in terms of paying guardians and raising tree seedlings. The windbreaks will need to be managed through cutting and replacement of trees as they age. CARE is exploring the possibility of establishing a cooperative of the valley's residents to manage the windbreaks, financing their activities through the sale of firewood. Whether this is a realistic option remains to be seen --

rural residents themselves may not have the money to purchase firewood. Transport costs to outside markets would be high.

In a few cases, individual farmers have extended the windbreak lines by planting trees on their own land. In general, however, this type of project cannot be easily undertaken by individuals, as it is a large-scale resource management strategy. CARE plans to expand the project scope, by building terraces and dikes on the hillsides above the Majjia. These efforts would be directed at stabilizing the slopes, to minimize soil erosion, and thus complement the impacts of the windbreaks.

CARE's foresters attribute the project's success to a number of factors. First, the local forester, Daouda, had excellent rapport with the villagers, and second, he also had the backing of local authorities. Third, the project responded to a problem that the valley's residents themselves had identified -- the need to combat wind erosion. Fourth, the area was a fertile site, where the agricultural productivity was worth protecting and the trees planted had done well.[7] Finally, the project began on a small scale: only after encouraging results were obtained was the project expanded. CARE has started similar projects in five other areas in Niger, but it is too early to tell if they will be as successful as the Majjia Valley project. Thus, it is not yet clear whether this project can be replicated elsewhere, or whether is was merely a fortuitous combination of circumstances.[8]

Although overall prospects of combatting desertification in the Sahel seem very bleak, the Majjia Valley project holds out hope. For many Sahelian residents, for whom daily existence can be very precarious, the windbreaks offer hope that human action can mitigate climatic conditions ---- that people are not helpless when confronted with the blowin' of the wind.

Sincerely,

Paula J. Williams

Paula J. Williams
Forest and Society Fellow

ACKNOWLEDGEMENTS:

Dr. Steven Dennison and Steven Long, CARE's foresters working on the evaluation study, were both extremely generous with their time in explaining the project. I particularly appreciated Steve Long's tour of the Majjia Valley and his warm hospitality in Bouza. Information was also graciously provided by Judith Collins, CARE'S country director, and by CARE's two staff foresters, Michael Ahern and Amadou N'Tirgny Maiga. Anyone seeking more information on the project can contact staff members at: CARE International, BP 10155 Niamey, Niger.

NOTES:

1. Technically, the trees constitute "windscreens" rather than true "windbreaks" because they do not totally stop the wind. Usually windbreaks are designed with several layers of vegetation, rather than a single canopy stratum, to block the wind. The windscreens permit the passage of some air: this may be advantageous in reducing field temperatures, so that the cereal crops do not bake in the sun as they grow.

2. The principal species planted has been neem (Azadirichta indica), but Acacia seyal, Acacia scorpioides, Prosopis chilensis, Prosopis juliflora, and Eucalyptus camaldulensis have also been used.

3. The government of Niger is administratively organized into Departements, which are subdivided into Arrondisements. The government officials for these two levels are appointed by the central national government. At each level, the head official is the Prefet, and his assistant is the Sous-Prefet. Arrondisements are furthered divided into Cantons, composed of several villages. The Canton Chiefs and village chiefs are chosen on a local, rather than national, basis.

4. Daouda made these remarks at the Atelier Multidisciplinaire sur la Planification Forestière au Niger - Phase Niamey/Dosso (Multidiciplinary Workshop on Forestry Planning in Niger), in Niamey on 13 February 1985.

5. Els Bognetteau-Verlinden. 1980. Study of Impact of Windbreaks in Majjia Valley, Niger.

6. Coppicing is cutting the tree trunks close to the ground, whereas pollarding consists of cutting the branches out of the crown, above the trunk. Partial pollarding consisted of cutting the outer branches that extended over the fields. For the seven to nine-year-old neems that were cut, the best regeneration rates were obtained with the full pollard cuts.

7. Due to low rainfall in 1984, the trees planted this past season only had a 30 percent survival rate. These windbreak lines will probably have to be replanted this coming rainy season.

8. Comments of Steven Dennison and Michael Ahern, made at the Atelier Multidisciplinaire sur la Planification Forestière au Niger (see note 2), and of Amadou N'Tirgny Maïga, at the Seminaire PNUD/CONGAD sur le Reboisement (Seminar of UNDP/CONGAD on Reforestation), in Dakar on 26 February 1985.

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Received in Hanover 3/13/85

SECTION VII

FAO FORESTRY PAPER 12

china: forestry support for agriculture

report on a fao/undp study tour to the people's republic of china

11 august - 30 september 1977

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome 1978

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4.3.4 Benefits of Shelterbelts

The Chinese emphasized the importance of shelterbelts on several sites by saying that shelterbelt forestry was a pre-requisite for the increase of agricultural crops. Other factors like irrigation, fertilization, improved seeds, mechanization, etc. came next in importance. This appears to be true, if one considers the benefits reported from shelterbelts, as follows:

(i) Supply of Timber and Fuelwood Requirements

The problem of firewood is solved in many parts of China by the establishment of shelterbelts (and other forms of forestry). Between 1966 and 1976, the Tungfanghung Production Brigade harvested 3 000 m^3 of firewood from shelterbelts for its own requirements and also supplied some other brigades. Thus dung, used previously for fuelwood, is preserved for manuring the farmlands. The firewood is sold to the members of the production brigade at one-third of the market price.

Between 1966 and 1976 the income from forestry of the Tungfanghung Production Brigade was 319 000 yuan, mainly from the sale of timber to the state. This made it possible for them to purchase agricultural machinery, fertilizers, irrigation equipment and other implements.

Growth rates for ten-year-old poplars grown in a shelterbelt were given on site at the Taipingti Commune, Chifeng County, Liaoning Province. They are as follows:

Table 2

GROWTH RATES OF POPLARS IN A SHELTERBELT

Planting date: 1966
Measurement date: 1976

Species	Average Height (m)	Average Diameter at Breast Height (DBH)(cm)
Populus canadensis	18.8	20.2
P. pekinensis	16.4	19.3
P. pyramidalis	16.1	17.1
P. simonii	11.3	13.5

In another belt of P. canadensis planted in 1966 and measured in 1976, average height was 21 m and average DBH was 21.5 cm. The total volume of 1 km of this belt 10 m wide (equivalent to 1 ha) was 563.3 m^3 or an increment of 56.33 m^3/ha/year.

The rotation for poplars has been fixed at 20 years, after which the belts are clear-felled.

The measurements for Ulmus pumila in the former belt were 11.2 m and 14.5 cm for average height and DBH respectively.

(ii) Improvement of the Microclimate

Shelterbelts can help regulate the microclimate and improve the environment for agricultural crops, thus increasing their yields. Behind shelterbelts wind speed is reduced, thus affecting all microclimatic factors to the benefit of the growing crops. The following figures compare some effects in two sites visited:

Table 3

EFFECTS OF SHELTERBELTS ON MICROCLIMATE

Effects of Shelterbelt	Chifeng County, Liaoning Province 4 rows, 8 m wide, 20 m high Populus spp.	Yu County, Henan Province 1 row, 40 m apart, 20 m high Paulownia spp.
Wind speed reduction	58%	14–30%
Temp. reduction (spring and summer)	1°C	0.4–2.2°C
Temp. increase (autumn and winter)	1°C	0.4–2.0°C
Evaporation reduction	38%	12–25%
Relative humidity increase	7%	13–20%
Grain yield increase	30–50%	13–17%

(iii) Protection of Seeds and Fruit and Lengthening of Season

Shelterbelts protect seeds and seedlings from burial by sands. Moreover, seed broadcasting in spring can be done earlier, and the growing season for crops can thus be extended. Harvesting in autumn is done without shattering of fruits and seeds.

The following figures were given for grain production in Chifeng County, Liaoning Province:

Year	Yield
1950	460 kg/ha
1965	3 020 "
1971	6 382 "
1972	6 765 "
(This was said to be a very dry year)	
1973–76	7 500 kg/ha

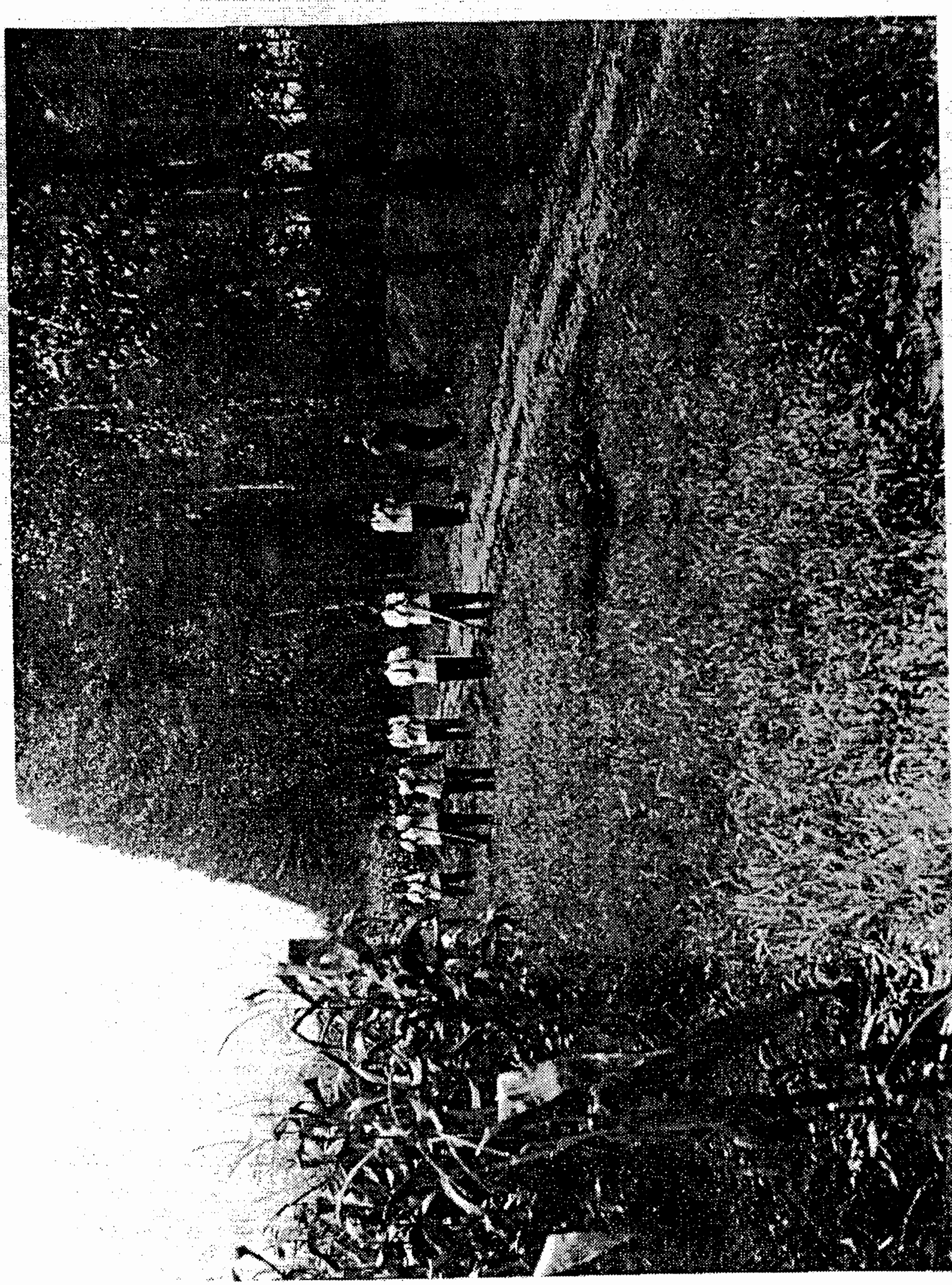

Fig. 4 Shelterbelt: Protection and Increased Yield, Liaoning Province

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No doubt factors other than shelter contributed to the increase shown above. However, shelterbelts can have a major effect especially in severe climatic conditions, as in 1972, which was said to be a very dry year.

(iv) Protection of Canals

Shelterbelts protect irrigation canals from sand burial. River banks are protected and stream flow is regulated. Thus river floods are smooth and can be used for irrigating the farm lands.

(v) Promotion of Animal Husbandry

In the Tungfanghung Production Brigade, there were only a few animals (one mule, three horses and a few pigs) before the establishment of shelterbelts. Today there are 670 head of animals, or three per household.

(vi) Promotion of Side-line Occupation

Under shelter, fishing was improved. In the Tungfanghung Production Brigade, a pond 1.5 ha in area was supporting about 50 000 fish.

4.3.5 The Disadvantages of Shelterbelts

The Chinese claim that until now only two disadvantages of shelterbelts have been encountered. The first is that shelterbelts occupy part of the farmlands and this is inevitable as they are a pre-requisite to farming practices. The second is that shelterbelts shade crops, thereby decreasing yield in shaded areas. This, we were told, is a very secondary harm and can be solved by realignment of roads and canals.

4.4 SAND-DUNE STABILIZATION

The group saw two distinct types of sand-dune stabilization activities, i.e. levelling of inland dunes and establishment of coastal windbreaks.

4.4.1 Levelling of Inland Dunes

These activities were observed in one commune and one production brigade in Chifeng County and one production brigade in Yu County. These areas were examples of the general sand-dune problems that are commonly found in the desert sands of the north and north-western interior of China. The dunes are formed by the sands blown from the desert which cover the cultivated land, canals, roads, etc., owing to lack of protection and proper land use practices.

The two separate places visited in Chifeng County, Tungfanghung Production Brigade and Taipingti Commune, were known for their poverty in the past. The precipitation is very low, ranging from an annual average of 300-400 mm (maximum of 490 mm and minimum of 204 mm); the evaporation rate is about four times as much as the annual precipitation. South-west winds in summer and north-west winds in autumn and winter are the prevailing winds, with a speed of 4 m/sec annual average up to 29 m/sec as a maximum; in any particular year there are 100-150 days of very strong winds, out of which 45 to 71 days are days with maximum wind speed. As a result, thousands of sand-dunes were formed. For example in Tungfanghung Production Brigade alone there were 20 000 sand-dunes and some of them covered an area of between 0.1 to 0.5 ha each.

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The people of Tungfanghung Production Brigade were mobilized to level the dunes by moving two million m^3 of sand, thereby turning the sand-dunes into land suitable for agricultural crops. After being levelled, the land was flooded with water in order to be enriched with silt deposits. Thus, man-made soil reached a depth varying from 0.30 to 1 m within ten years; nitrogen increased 4.1 times, phosphorus 1.3 and potassium 1.4 times. This development was completed by establishing shelterbelts around the fields and linking the land with irrigation pumps and a canal system. The grain yield was more than tripled. Wind damage was completely eliminated; in fact, in 1963 very strong winds occurred in the neighbourhood, covering the land with six inches of sand, but thanks to these development measures Tungfanghung Production Brigade was not affected at all.

Similar climatic and environmental conditions, producing the same effects, existed in Paichuang Production Brigade in Yu County. Here 800 000 m^3 of sand were moved and the dunes converted into land suitable for agricultural crops in the same way.

In all three places visited small areas with the original dunes were kept as a reminder of old disasters, to serve as part of public education on proper land utilization.

4.4.2 Coastal Windbreaks

The group visited Nanshan Island, Guangdong (Kwangtung) Province, where 57 km of coastal windbreaks have been established in the last 20 years to protect the island from the north-east winds which blow sands onto the farmlands, from typhoons in summer and from the sea which used to destroy the arable land and houses annually. It was said that before the establishment of coastal windbreaks the island suffered badly from heat and typhoons.

Nanshan Island was originally composed of ten islands (as mentioned earlier in chapter 1, section 1.3) which have now been linked together by the people. It has an area of 122 km^2 with a population of 51 000 people.

Before 1949, this island was characterized by shifting sands and sand-dunes and the area was barren and without trees. Agricultural production was likewise extremely poor and the area was often struck by typhoons and very strong winds which blew almost all year round. Between 1929 and 1949 the sea came in about 2 km and 120 ha of cropland were covered by sand.

The soils are sandy and the climate sub-tropical, with an average annual temperature of 23.6°C, an absolute maximum temperature of 37°C and an absolute minimum temperature of 2°C. Average annual rainfall is 1,400–1,600 mm and there are two distinct seasons, a dry season from October to April and a rainy season from May to September.

Tree planting started in 1953. By 1954, 19 300 trees had been planted, even though the survival rate was low because of lack of experience. By 1956 large-scale plantation had been initiated through mass mobilization and by 1964 some 3,933 ha of land had been planted with Casuarina. This rate of planting continued and by 1976 the island had a total of 57 km of coastal windbreaks covering 4,034 ha of land.

The width of the coastal windbreaks runs from 1 to 5 km, thus giving total inland protection from sand and tidal water. As a result wind speed has been reduced by 60 percent, daily average temperature by 0.2–8.3°C, ground surface temperature by 1.3–2.0°C and evaporation by 12.5 percent. Relative humidity has increased by 7 percent.

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Yield of agricultural crops increased from 1.4 tonnes/ha before 1949 to 4.8 tonnes/ha in 1976. Furthermore, 2,200 ha of land have been reclaimed by linking the islands, 1,200 ha of which have been used for agriculture.

Before the establishment of the windbreaks firewood had to be transported to the island. After 1964, the windbreaks began supplying wood; timber was sold to the state and timber for 20,000 new houses was also made available. At present, more than 10,000 m^3 of timber are supplied to the state and 2,100 tonnes of firewood to neighbouring cities annually.

The revenue of the island from forestry is about 700,000 yuan annually.

The species used is Casuarina equisetifolia. It is grown from seed, which is sown in January and February. The seedlings are transplanted in March-April into soil blocks covered with straw. Tap roots are cut when they are transplanted.

The seedlings are planted out in July-September. Before planting, the roots are pruned. The spacing is 2 x 2 m and pits are of 40 x 40 cm. No manuring is applied. Every year five rows are planted toward the sea.

The cost of establishing one ha of coastal windbreaks (including nursery) was given as 120 yuan.

The rotation period ranges from 10-15 years depending upon growth conditions and plan requirements. The yield is 45 m^3/ha, which is about 4-5 m^3/ha/year. Each year 40 ha are cut and the area is immediately replanted. The wood is mainly used for constructing houses as well as large-sized boats and furniture.

4.5 AFFORESTATION OF BARE MOUNTAINS

4.5.1 General

Afforestation of bare mountains forms part of the integrated land-use plan at all levels. This type of activity is undertaken either in the context of protection or production forestry.

Since afforestation of bare mountains was classified as a separate activity from watershed management and plantation of fast-growing species for timber production by the Chinese organizer of the study tour, it is distinguished from them here and they are dealt with separately in the following paragraphs.

Production plantation is carried out either to enrich existing secondary forest areas with species producing timber or edible oil or to replace old, unsatisfactory Pinus massoniana plantations. Expecially in the first case, the land is clean cultivated, old stumps are uprooted and the existing vegetation is completely eliminated. This clean cultivation, with or without terracing, causes a lot of soil erosion, especially during the early years of establishment. In most cases paths to the top of the hill are so straight that they encourage soil erosion and deep gully formation. Most of this plantation is carried out on land which is unsuitable for agriculture and it serves to produce timber or fuelwood to meet national and local requirements. Furthermore, trees are planted around pastures and grazing land for the same purpose.

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4.5.2 Main Species Used and Observed

The following species are used in all kinds of plantations:

In Liaoning Province: Populus chifungensis, P. simonii, P. nigra, P. pyramidalis, P. canadensis, P. pekinensis, Salix spp., Ulmus pumila, Amorpha fruticosa, Robinia pseudo-acacia, Pinus tabulaeformis.

In Henan (Honan) Province: Paulownia fortunei, Populus spp., Salix spp., Ulmus pumila, Platanus orientalis, Diospyros kaki, Ziziphus jujuba, Melia azedarach, Toona sinensis, Populus tomentosa, Populus dakuanensis, Paulownia lankanensis.

In Hubei (Hupeh) Province: Cunninghamia lanceolata, Pinus massoniana, Larix koreana, L. sibirica, L. principis, Pseudosassafras laxiflora, Glyptostrobus pensilis, Pterocarya stenoptera.

In Hunan Province: Paulownia spp., Populus spp., Salix spp., Cunninghamia lanceolata, Pinus elliottii, P. massoniana, Pseudosassafras latifolia, Toona sinensis, Aleurites montana, A. fordii, Camptotheca acuminata, Osmanthus fragrans, Sapindus mukurosi, Cinnamomum camphora, Podocarpus macrophylla, Acer davidii, A. mono, Platanus orientalis, P. acerifolia, Taxodium distichum, T. ascendens Ligustrum lucidum, Sassafras tsumu, Magnolia grandiflora.

In Guangdong (Kwangtung) Province: Alstonia scholaris, Michelia alba, Acacia confusa, Aleurites moluccana, Bombax malabaricum, Melaleuca leucadendron, Chukrasia tabularis, Ficus retusa, F. lancor, Casuarina equisetifolia, Eucalyptus exserta, E. citriodora, E. leichow no. 1, Artocarpus heterophylla.

4.6 WATERSHED MANAGEMENT

Although watershed management is not used as a common term, land utilization in accordance with the principles of soil and water conservation is explicitly covered in the integrated planning procedure in China. In the hilly areas, hydrological effects of afforestation are recognized in regulating the stream flow. Improvement of water quality and erosion control are the main objectives of this type of activity. As water is the key to food production, many projects centre around the development of irrigation systems which, along with the massive tree-planting programme and management methods and techniques, will have a long-term effect on the hydrological regime of the watersheds.

A land capability classification is adopted for delineating areas for agriculture and permanent vegetation cover (it includes forests and forest plantations). All lands with a slope of up to 15° and a suitable soil are reserved for agriculture, while those with a slope of over 15° are reserved for forests, as are lands with a slope of up to 15° and poor soil. Tree planting over areas with a serious erosion hazard is emphasized.

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SECTION VIII

AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C. 20523

INFORMATION MEMORANDUM

SUBJECT: Availability of Other S&T/FENR Agro-forestation TECHNICAL SERIES Publications

Information on other subjects is available in the S&T/FENR Agro-forestation TECHNICAL SERIES given below. The numbering of this series has little relevance to the chronological order of the articles, publications or compilations. Rather, this is a list of subjects that I put together based on information that I feel is not easily available to field people. At that time, I gave a SERIES # to each subject on my list, and when I have enough information to cover the subject adequately, I complete the compilation. As new subjects come to light, I add them to the list.

As of this date, TECHNICAL SERIES # 1, 2, 4, 6, 7, 10, and 14 through 29 are available. If you desire additional copies or a copy of one which you have not received, or would like me to mail copies to host country technicians or others, let me know and I will send the copies requested.

#1. Selected Tree Seed Sources in Australia, India, Holland and the United States. However, this publication is dated, and I suggest that you send for a copy of Multipurpose Tree & Shrub Seed Directory (May 1986), International Council for Research in Agroforestry (ICRAF), P.O. Box 30677, Nairobi, Kenya.
#2. The Potential of Starch Graft Polymers "Super Slurpers" for Forestry and Agriculture
#3. Minimizing Livestock Damage to Trees Through the Use of Trenching, Living Fences and Game Repellant
#4. The Comparative Advantages and Disadvantages of Root Trainers, Dibble Tubes, Plastic Bags and Bare-Rooting
#5. Neem (Azadirachta indica juss): The Cornucopia Tree
#6. Windbreaks, Shelterbelts and Sand Dune Stabilization
#7. Growth Yield Increase of Trees Through Fertilization
#8. Ground Preparation: Hillside Ditching, Catchment Systems, Trenching, Placement of Trees on Terraces to Increase Establishment and Growth Rate of Trees
#9. Advantages of Vegetative Propagation and Tissue Culture for Seed Orchard Establishment
#10. Casaurinas: Trees of Promise
#11. Termite and Rodent Protection for Seedlings and Trees

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#12. (S&T/AGR Tech Series Bull. #26) Agroforestry Systems Using Contour Hedgerows for Soil Erosion Control, Plant Material Reproduction, Soil Improvement and Forage and Fuelwood Production
#14. Jojoba: A Promising New Crop For Arid Lands
#15. Solar Curing Barns, Fast-Growing Trees and Agroforestry Offer A Solution to the Deforestation Caused by Tobacco Production in Thailand, Tanzania, Sri Lanka, Nepal, Philippines and Other Developing Countries
#16. Excerpts from: Evaluation of and Recommendations for Research on Fast-Growing Tree Species for Wood Energy Production in the Dendro-Thermal, Charcoal Production and Gasification for Irrigation Projects in the Philippines
#17. Leucaena leucocephala: A Tree That "Defies the Woodcutter"
#18. State-of-the-Art: Acacia albida
#19. Guide Book for Rural, Cottage and Small and Medium Scale Industries and Paddy Rice Cultivation
#20. Soils, Crops & Fertilizer Use (Peace Corps)
#21. Handbook of Tropical and Subtropical Horticulture (USAID)
#22. World Literature on Leucaena
#23. Paulownia, "The Princess Tree," an Excellent Candidate for Agroforestry
#24. Utilization of Neem (Azadirachta indica juss) and Its By-Products
#25. Leucaena leucocephala: An Excellent Feed for Livestock
#26. Living Yam Poles (English or French)
#27. Moringa: A Tree That Purifies Water and Whose Leaves and Fruits Are Rich in Vitamins A & C, Protein, Calcium, Iron and Phosphorus
#28. Fertilizing Fruit Trees with Leucaena and Other Legumes Results in Increased Growth and Yields
#29. Contour Hedgerows for Fodder, Planting Stock, Fuelwood and Increased Food Production and ror Minimizing Soil Erosion in Highland Regions

If you have any comments on the relevance of this information, I would like to hear from you.

M

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January 14, 1987

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